KPK BOARD NOTES

# PHYSICS

# 10TH CLASS

Presented by:

Urdu Books Whatsapp Group

STUDY GROUP


0333-8033313
راؤایاز

0343-7008883
پاکستان زندہ باد

0306-7163117
محمد سلمان سلیم

CHAPTER 10

# SIMPLE HARMONIC MOTION & WAVES

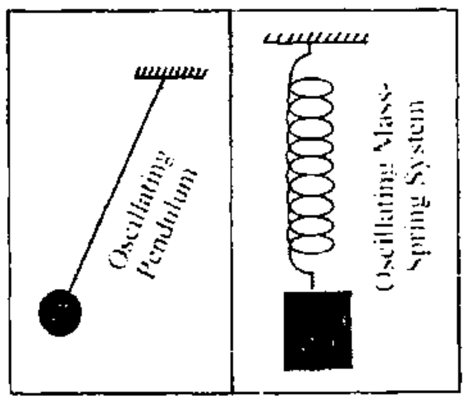
**Q1: Define oscillatory motion. Explain with examples.** ارتعاشی حرکت سے کیا مراد ہے؟ مثالوں سے وضاحت کریں۔

**Ans. Oscillatory Motion (ارتعاشی حرکت):**

(BISE Swat 2019)

"The to and fro motion of a body about its mean position is known as oscillatory motion".

(OR) "The back and forth motion of a body about its equilibrium position is known as oscillatory motion".




**Explanation (وضاحت)**

The oscillatory motion is also known as vibratory motion. If a body moves back and forth over the same path, then such motion of the body is known as oscillatory motion.

**Examples (مثالیں)**

The examples of oscillatory motion are given below:

1. Motion of simple pendulum
2. Motion of wires of sitar and violin
3. Motion of a body attached to an elastic spring

**Q2: Define periodic motion· Explain with examples· Find the relation between the frequency and time period of a periodic motion·**
دوری حرکت سے کیا مراد ہے؟ مثالوں سے وضاحت کریں۔ اس کی فریکوئنسی اور ٹائم پیریڈ میں تعلق بیان کریں۔

Ans· Periodic Motion (دوری حرکت)

"The motion which repeats its self in equal intervals of time is known as periodic motion"·

Examples (مثالیں)

1· Motion of simple pendulum
2· Motion of mass-spring system
3· Motion of metallic strip (فولادی پٹی)

Relation between frequency and time period

If "T" represents the time period and "f" represents the frequency, then we have,

$$\boxed{f = \frac{1}{T}} \qquad (1)$$

Equation (1) represents the relation between frequency and time period of periodic motion·

**Q3: Define simple harmonic motion· Describe its characteristics features·**
سادہ ہم آہنگ حرکت کی تعریف کریں۔ اس کی خصوصیات بیان کریں۔

Ans· Simple Harmonic Motion (سادہ ہم آہنگ حرکت):
(BISE Bannu, Swat, Kohat 2019)

"The motion in which the acceleration of the body is directly proportional to the displacement from its mean position is known as simple harmonic motion"·

Explanation (وضاحت)

If "a" represents the acceleration of the body and

"x" represents the displacement of the body from its position, then we have,

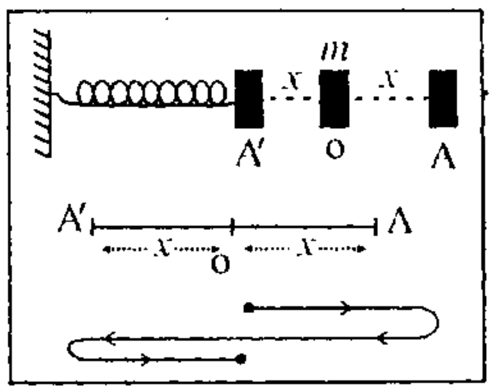
$a \propto (-x)$ _________ (1)

Relation (1) represents the mathematical form of simple harmonic motion.

The negative sign shows that, the body is always directed towards the mean position.

## Characteristics of Simple Harmonic Motion

Consider a body of mass "m" attached to an elastic spring, as shown in the figure.




If the body is displaced towards right position "A" through a displacement "x" from its mean position "O", then on releasing the body at position "A", the body comes back towards the mean position "O" due to restoring force (بحال کن قوت) "F".

On the way, its velocity increases due to which the body does not stop at mean position "O" and moves towards left position "A' ". Again due to restoring force "F", the body comes back towards the mean position "O". In this way, the body performs simple harmonic motion.

During this motion, the following characteristics can be observed:

1. In simple harmonic motion, the body oscillates about its mean position "O".

ختم نبوت صلی اللہ علیہ وسلم زندہ باد — عظمت صحابہ زندہ باد

**السلام علیکم ورحمۃ اللہ وبرکاتہ:**

معزز ممبران: آپ کا وٹس ایپ گروپ ایڈ من "**اردو بکس**" آپ سے مخاطب ہے۔

**آپ تمام ممبران سے گزارش ہے کہ:**

- گروپ میں صرف PDF کتب پوسٹ کی جاتی ہیں لہذا کتب کے متعلق اپنے کمنٹس / ریویوز ضرور دیں۔ گروپ میں بغیر ایڈ من کی اجازت کے کسی بھی قسم کی (اسلامی وغیر اسلامی، اخلاقی، تحریری) پوسٹ کرنا سختی سے منع ہے۔
- گروپ میں معزز، پڑھے لکھے، سلجھے ہوئے ممبرز موجود ہیں اخلاقیات کی پابندی کریں اور گروپ رولز کو فالو کریں بصورت دیگر معزز ممبرز کی بہتری کی خاطر ریموو کر دیا جائے گا۔
- کوئی بھی ممبر کسی بھی ممبر کو انباکس میں میسیج، مس کال، کال نہیں کرے گا۔ رپورٹ پر فوری ریموو کر کے کاروائی عمل میں لائے جائے گی۔
- ہمارے کسی بھی گروپ میں سیاسی و فرقہ واریت کی بحث کی قطعاً کوئی گنجائش نہیں ہے۔
- اگر کسی کو بھی گروپ کے متعلق کسی قسم کی شکایت یا تجویز کی صورت میں ایڈ من سے رابطہ کیجئے۔
- سب سے اہم بات:

**گروپ میں کسی بھی قادیانی، مرزائی، احمدی، گستاخِ رسول، گستاخِ امہات المؤمنین، گستاخِ صحابہ و خلفائے راشدین حضرت ابو بکر صدیق، حضرت عمر فاروق، حضرت عثمان غنی، حضرت علی المرتضیٰ، حضرت حسنین کریمین رضوان اللہ تعالیٰ اجمعین، گستاخ اہلبیت یا ایسے غیر مسلم جو اسلام اور پاکستان کے خلاف پراپیگنڈا میں مصروف ہیں یا ان کے روحانی و ذہنی سپورٹرز کے لئے کوئی گنجائش نہیں ہے لہذا ایسے اشخاص بالکل بھی گروپ جوائن کرنے کی زحمت نہ کریں۔ معلوم ہونے پر فوراً ریموو کر دیا جائے گا۔**

- تمام کتب انٹرنیٹ سے تلاش / ڈاؤنلوڈ کر کے **فری آف کاسٹ** وٹس ایپ گروپ میں شیئر کی جاتی ہیں۔ جو کتاب نہیں ملتی اس کے لئے معذرت کر لی جاتی ہے۔ جس میں محنت بھی صَرف ہوتی ہے لیکن ہمیں آپ سے صرف دعاؤں کی درخواست ہے۔
- عمران سیریز کے شوقین کیلئے علیحدہ سے عمران سیریز گروپ موجود ہے۔
- **لیڈیز کے لئے الگ گروپ کی سہولت موجود ہے جس کے لئے ویریفکیشن ضروری ہے۔**
- اردو کتب / عمران سیریز یا سٹڈی گروپ میں ایڈ ہونے کے لئے ایڈ من سے وٹس ایپ پر بذریعہ میسیج رابطہ کریں اور جواب کا انتظار فرمائیں۔ برائے مہربانی اخلاقیات کا خیال رکھتے ہوئے موبائل پر کال یا ایم ایس کرنے کی کوشش ہر گز نہ کریں۔ ورنہ گروپس سے تو ریموو کیا ہی جائے گا بلاک بھی کیا جائے گا۔

**نوٹ: ہمارے کسی گروپ کی کوئی فیس نہیں ہے۔ سب فی سبیل اللہ ہے**

| | | |
|---|---|---|
| 0306-7163117 | 0343-7008883 | 0333-8033313 |
| محمد سلمان سلیم | پاکستان زندہ باد | راؤ ایاز |

پاکستان زندہ باد — پاکستان پائندہ باد

اللہ تبارک تعالیٰ ہم سب کا حامی وناصر ہو

2. The distance of the body from mean position is known as displacement. It is represented by "x".
3. The maximum displacement of the body from its mean position is known as amplitude. It is represented by "$x_m$" or '$x_o$".
4. In simple harmonic motion, the acceleration of the body is directly proportional to its displacement from mean position "O". i.e. $a \propto (-x)$
5. The velocity of the body is zero at extreme (انتہائی) position and maximum at mean position "O".
6. At mean position, the energy of the body is in the form of kinetic energy (K.E).
7. At extreme position, the energy of the body is in the form of potential energy (P.E).
8. The total energy remains constant during simple harmonic motion.
9. Time period of mass-spring system is given by

$$T = 2\pi \sqrt{m/k}$$

10. The frequency of mass-spring system is given by

$$f = \frac{1}{2\pi}\sqrt{k/m}$$

**Q4: Define the following terms: Vibration / cycle, time period, displacement, frequency and amplitude** مندرجہ ذیل اصطلاحات کی تعریف کریں: ارتعاش یا سائیکل، ٹائم پیریڈ، فریکوئنسی، ہٹاؤ اور حیطہ

Ans. (1) Vibration (or) Cycle (ارتعاش یا سائیکل)

A complete round trip of an oscillating body about its mean position is known as vibration (or) cycle.

(2) Time Period (ٹائم پیریڈ)

The time during which one vibration is complete is known as time period. it is denoted by "T".

(3) Frequency (فریکوئنسی)

The number of vibrations per second is known as frequency. It is represented by 'f'. Its units are vibration / sec, cycle / sec, hertz etc.

(4) Displacement (ہٹاؤ)

The straight distance of a vibrating body from mean position is known as displacement. It is represented by "x".

(5) Amplitude (حیطہ)

The maximum displacement of a vibrating body from mean position is known as amplitude. It is represented by "$x_o$". The displacement and amplitude are measured in meter.

(6) Relation between frequency and time period

The relation between frequency and time period is given by, $f = \frac{1}{T}$

**Q5: What is simple harmonic motion [S.H.M]? What are the conditions for an object to oscillate with simple harmonic motion?**

سادہ ہم آہنگ حرکت سے کیا مراد ہے؟ کسی جسم کا سادہ ہم آہنگ حرکت کرنے کیلئے شرائط بیان کریں۔

Ans. Simple Harmonic Motion (سادہ ہم آہنگ حرکت)

(BISE Swat, Bannu, Kohat 2019)

"The motion in which the acceleration of the oscillating body is directly proportional to the displacement from its mean position is known as simple harmonic motion".

## Explanation (وضاحت)

If "a" represents the acceleration of the oscillating body and "x" represents the displacement from its mean position, then we have,

$$a \propto (-x) \longrightarrow (i)$$

Relation (i) represents the mathematical form of simple harmonic motion. The negative sign shows that, the body is directed towards the mean position due to restoring force.

## Conditions for an object to oscillate with S.H.M

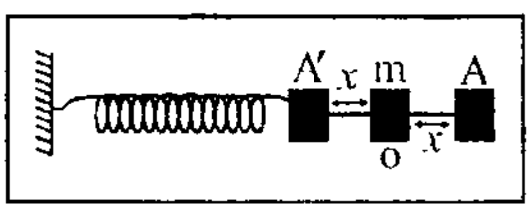
For a body executing S.H.M, the following conditions must be satisfied:

1. The displacement of the oscillating body should be kept small.
2. The motion should be performed along same straight path about the mean position.
3. The motion should be performed under the action of restoring force.
4. The relation "$a \propto (-x)$" should be satisfied.
5. The motion should be repeated in equal intervals of time.

**Q6: Show that the mass-spring system executes simple harmonic motion.**

ثابت کریں کہ سپرنگ سے منسلک شدہ جسم کی حرکت سادہ ہم آہنگ حرکت ہوتی ہے۔

Ans. Consider a body of mass "m" attached to the end of an elastic spring as shown in the figure.




Now if we displace the

*body from its mean position "O" to the extreme position "A", then on releasing the body at "A", the body comes back towards the mean position "O" due to restoring force "F".*

*On the way, its velocity increases due to which the body does not stop at mean position "O" and moves towards left side of mean position. Again due to restoring force, the body comes to rest at extreme position "A′" and then moves back towards the mean position "O".*

*On the way, again its velocity increases due to which it does not stop at "O" and moves towards right of mean position. In this way, the body performs S.H.M about mean position. Now according to Hooke's law, we have,*

$$F \propto (-x) \Rightarrow F = -kx \quad \text{__________} \quad (1)$$

*The negative sign shows that the body is always directed towards the mean position. Now according to Newton 2nd law, we have*

$$F = ma \quad \text{__________} \quad (2)$$

*Comparing equation (1) and equation (2), we get*

$$ma = -kx \Rightarrow a = -\left(\frac{k}{m}\right)x \quad \text{__________} \quad (3)$$

$$\Rightarrow \quad a = \text{constant } (-x)$$

$$\Rightarrow \quad \boxed{a \propto (-x)} \quad \text{__________} \quad (4)$$

$$\left[k/m = \text{constt}\right]$$

*Relation (4) represents the mathematical form of S.H.M, so the mass-spring system executes simple harmonic motion [S.H.M].*

**Time Period (ٹائم پیریڈ)**

The time period in terms of angular frequency "ω" is given by,

$$T = 2\pi/\omega \quad \text{------} \quad (5)$$

In equation (5) "ω" represents the angular frequency i.e. the measure of angular displacement per unit time.

The acceleration in terms of "ω" is given by,

$$a = -\omega^2 x \quad \text{------} \quad (6)$$

Comparing equation (iii) and (6), we get,

$$\omega^2 = k/m \text{ or}$$

$$\omega = \sqrt{k/m} \quad \text{------} \quad (7)$$

Putting equation (7) in equation (5), we get,

$$T = 2\pi/\sqrt{k/m}$$

$$\Rightarrow \boxed{T = 2\pi\sqrt{m/k}} \quad \text{------} \quad (8)$$

Equation (8) represents the time period of mass-spring system.

**Frequency (فریکوئنسی):**

We know that,

$$f = \frac{1}{T} \quad \text{------} \quad (9)$$

Putting equation (8) in equation (9), we get,

$$\boxed{f = \frac{1}{2\pi}\sqrt{k/m}} \quad \text{------} \quad (10)$$

Equation (10) represents the frequency of mass-spring system.

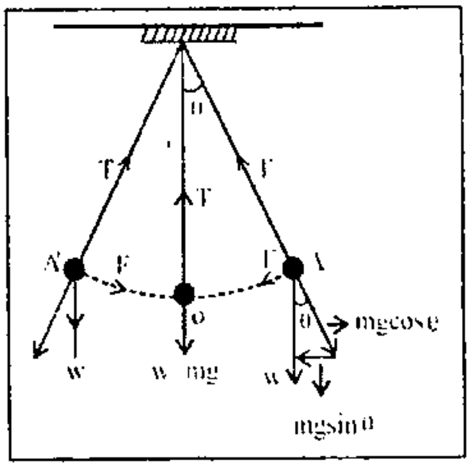
***Q7: What is simple pendulum? Diagrammatically show the forces acting on the simple pendulum. Also show that simple pendulum execute simple harmonic motion.***

سادہ پنڈولم کیا ہے؟ سادہ پنڈولم پر لگنے والے قوتیں شکل کے ذریعے واضح کریں۔ یہ بھی ثابت کریں کہ سادہ پنڈولم کی حرکت سادہ ہم آہنگ حرکت ہوتی ہے۔

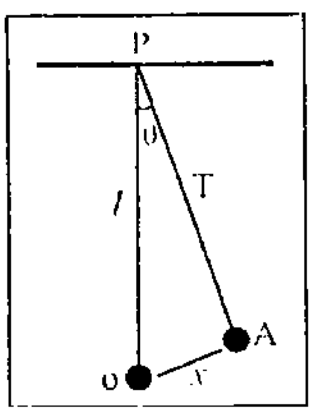
*Ans. Simple Pendulum (سادہ پنڈولم)*

*A simple pendulum consists of a small and heavy metallic spherical bob which is suspended by a light and inextensible string from a fixed support.*

*Explanation (وضاحت)*




*Consider a simple pendulum as shown in the figure. At mean position "O" the weight "w" of the pendulum is acting in downward direction while the tension "T" in the string is acting in upwards direction, as shown in figure. Now if we bring the bob from mean position "O" to extreme position "A", then its weight "w" is resolved into two components i.e., "mgcosθ" and "mgsinθ".*




*The component "mgcosθ" balance the tension "T" in the string. While the component "mgsinθ" is acting towards the mean position "O". So "mgsinθ" acts as restoring force. So we have,*

$$\boxed{mg\cos\theta = T} \quad ________ (1)$$

And $\boxed{F = -mg\sin\theta}$ ________ (2)

Now according to Newton's 2nd law, we have,

$$\boxed{F = ma} \quad ________ (3)$$

Comparing equation (2) and equation (3), we get,

$$ma = -mg\sin\theta$$

$$\Rightarrow \quad \boxed{a = -g\sin\theta} \quad ________ (4)$$

Now in triangle "ΔOPA", we have

sin θ = perpendicular / hypotenuse

$$\Rightarrow \quad \boxed{\sin\theta = \frac{x}{l}} \quad ________ (5)$$

Putting equation (5) in equation (4), we get,

$$a = -g \cdot \frac{x}{l} \quad \Rightarrow \quad a = \left(\frac{g}{l}\right)(-x) \quad ________ (6)$$

$$\Rightarrow \quad a = \text{constant } (-x)$$

$$\Rightarrow \quad \boxed{a \propto (-x)} \quad ________ (7) \qquad \left[\frac{g}{l} = \text{constt}\right]$$

Relation (7) represents the mathematical form of simple harmonic motion, so the simple harmonic pendulum executes simple harmonic motion.

<u>Time Period ([illegible]):</u>

The time period in terms of angular frequency "ω" is given by,

$$T = \frac{2\pi}{\omega} \quad ________ (8)$$

The acceleration in terms of "ω" is given by,

$$a = -\omega^2 x \quad ________ (9)$$

Comparing equation (6) and equation (9), we get

$$\omega^2 = \frac{g}{l} \Rightarrow \omega = \sqrt{\frac{g}{l}} \quad ________ (10)$$

Putting equation (10) in equation (8), we get

$$T = \frac{2\pi}{\sqrt{\frac{g}{l}}}$$

$$\Rightarrow \boxed{T = 2\pi\sqrt{\frac{l}{g}}} \quad \text{———— (11)}$$

Equation (11) represents the time period of simple pendulum.

Frequency (فریکوئنسی):

We know that,

$$f = \frac{1}{T} \longrightarrow (12)$$

Putting equation (11) in equation (12), we get

$$\boxed{f = \frac{1}{2\pi}\sqrt{\frac{g}{l}}} \quad \text{———— (13)}$$

Equation (13) represents the frequency of simple pendulum.

**Q8: What do you mean by damped oscillations? Also write the applications of damped oscillations.**
**مدھم شدہ ارتعاشات سے کیا مراد ہے؟ مدھم شدہ ارتعاشات کے عملی اطلاقات بیان کریں۔**

Ans. Damped Oscillations (مدھم شدہ ارتعاشات)

(BISE Peshawar 2019)

"The oscillations, in which the amplitude decreases steadily with time are called damped oscillations".

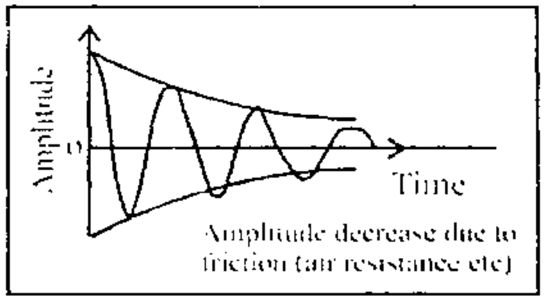
(OR)

"The process in which energy is dissipated from the oscillating system is called damped oscillations".

Explanation (وضاحت)

This is the common everyday experience that a bal-

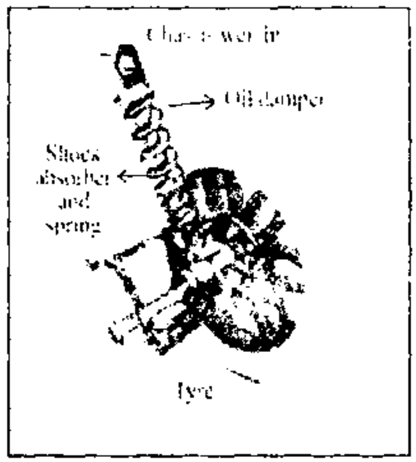
ance wheel of a watch will cease to oscillate unless some energy can be supplied to it from the watch spring. The effect of frictional forces is to reduce the total mechanical energy of the oscillating system.




A note played on a piano is loud immediately after it has been played and then gradually fades away.

Applications of Damped Oscillations

1. The shock absorber of a car is the practical application of damped oscillations. It provides a damping force to prevent excessive oscillations and thus provides comfortable journey. A shock absorber consists of a piston in a reservoir of oil. When the piston moves in response to a bump in the road, holes in the piston head permit the piston to pass through the oil. During this movement, viscous forces arises which cause the damping. As a result, we enjoy comfortable journey.




2. Another application of damped oscillation is the shock absorber system of human body. Skier's body moves over the bumpy snow

smoothly while his or her thighs and calves act like a damping spring.

**Q9: What is wave motion? How waves can be categorized?**

موج کی حرکت سے کیا مراد ہے؟ موجوں کی درجہ بندی کریں یا موجوں کی اقسام بیان کریں۔

Ans. **Wave and Wave Motion**

A wave is a traveling disturbance which carries energy from one place to another. The motion or propagation of waves occurs in the form of transverse waves or longitudinal waves.

**Types of Waves (موجوں کی اقسام)**

There are two main types of waves which are given below:

1. Mechanical Waves
2. Electromagnetic Waves

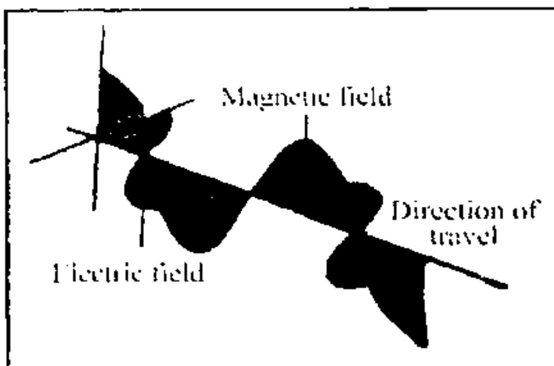
**1) Mechanical Waves (میکانی موجیں)**

Those waves which are produced due to the oscillation of material particles are called mechanical waves.

**Examples:** Water waves, sound waves, seismic waves, waves produced in a stretched string etc are the examples of mechanical waves.

**2) Electromagnetic Waves (برقناطیسی موجیں)**

The waves that propagate by oscillation of electric and magnetic fields are called electromagnetic waves.



Electromagnetic waves

The electromagnetic waves need no material medium for their propagation. The electromagnetic

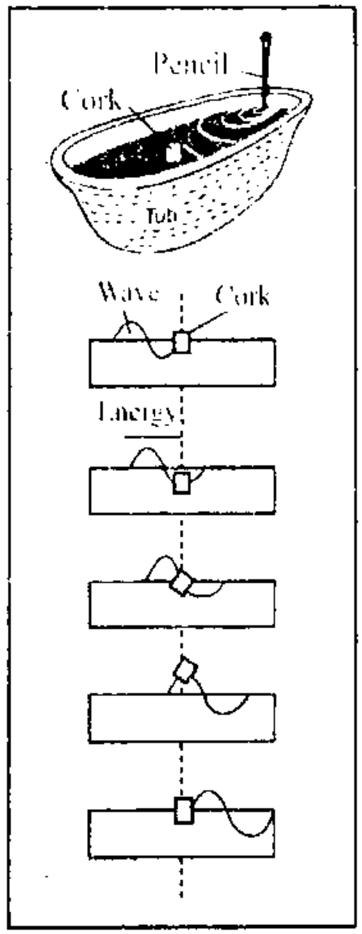
waves are the combination of travelling electric and magnetic fields. Both fields varies in magnitude and both oscillate at right angle to each other and to the direction of propagation of the wave.

Examples: Visible light waves, ultraviolet light waves, x-rays, microwaves and radio waves etc are the examples of electromagnetic waves.

**Q10: How waves transport energy without carrying the material medium? Also describe the connection between oscillatory motion and wave.**

مادی واسطے کے ذرات کے مستقل منتقلی کے بغیر موجیں توانائی کو کسی ایک جگہ سے دوسری جگہ منتقل کرتے ہیں؟ نیز ارتعاشی حرکت اور موجوں میں ربط پر بحث کریں۔

Ans. A wave is a disturbance which carries energy from one place to another. Wave transport energy without carrying the material medium. It can be explain with the help of following example:




Example: Take a tub and filled it with water. Now take a pencil and move it up and down at one edge of the tub. As a result, a disturbance is produce in the water. The particles of water begin to oscillate about their mean position. The disturbance spread out in the form of waves on the surface of water.

During the propagation of these waves, the particle of water [medium] does not change its position permanently. They perform only oscillatory motion. For example, if we place a piece of cork in the middle of the tub, the waves will spread out and will pass through the cork and will reach the edges. But the cork will still remains in the middle of the tub and will perform only up and down motion i.e. oscillatory motion. This shows that during propagation of waves, the particle of the medium does not change its position permanently and perform oscillatory motion only.

**Q11: What are mechanical waves? Discuss the types of mechanical waves.** میکانی موجیں کیا ہوتی ہیں؟ میکانی موجوں کی اقسام بیان کریں۔

Ans. Mechanical Waves (میکانی موجیں):

(BISE Kohat, Malakand 2019)

Those waves which require a material medium for their propagation are called mechanical waves.

Types of Mechanical Waves

There are two types of mechanical waves i.e.

1. Transverse Waves
2. Longitudinal Waves

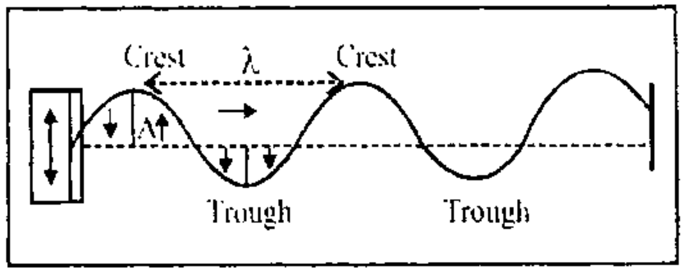
1) Transverse Waves (عرضی موجیں)

"These are those waves in which the disturbance occurs perpendicular to the direction of motion of the wave".

Explanation (وضاحت)

The transverse waves consist of crests and trough (نشیب اور فراز) which are produced one after the other in a certain order. The crest represents the part

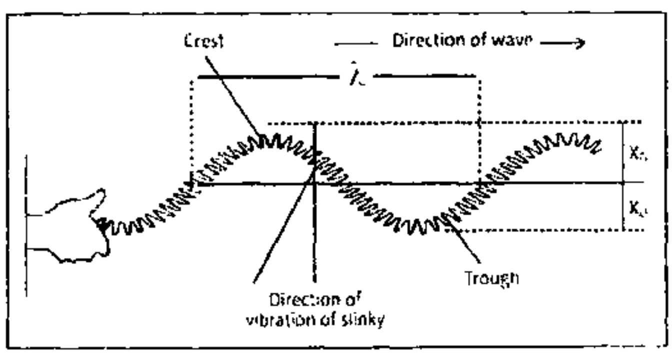
of wave above the equilibrium position while the trough represents the part of wave below the equilibrium position.




The distance between two nearest crests or two nearest trough is equal to wavelength "λ", while the distance between nearest crest and trough is equal to half of the wavelength i.e. "$\frac{\lambda}{2}$". The velocity, frequency and wavelength of transverse waves are related to each other by the following equation, i.e.,

$$v = f\lambda$$

## Production of Transverse Waves in Slinky




The transverse waves can be produced in a stretch string. They can be also generated in slinky. Slinky represents a long loosely coiled spring. If one end of the slinky is moved up and down continuously, then transverse waves is generated which move towards right, as shown in the figure.

## 2) Longitudinal Waves (طولی امواج)

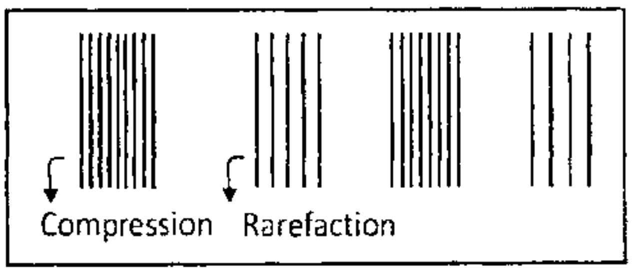
"These are those waves in which the disturbance

*occurs parallel to the line of travel of the wave".*

*Explanation*

*The longitudinal waves consist of compressions and rarefactions which are produced one after the other in a certain order.*

*Compression represents the regions of high density or pressure relative to the mean density or pressure of the medium. The rarefaction represents the regions of low density or pressure relative to the mean density or pressure of the medium.*

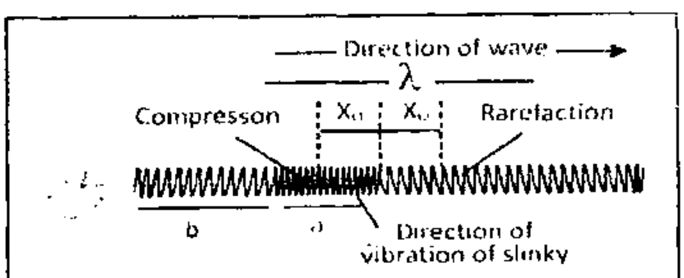



*The distance between two nearest compressions or two nearest rarefaction is equal to wavelength "λ", while the distance between nearest compression and rarefaction is equal to half of the wavelength i.e.* "$\frac{\lambda}{2}$". *The velocity, frequency and wavelength of these waves are related to each other by the following equation, i.e.,*

$$v = f\lambda$$

*Production of Longitudinal Waves in Slinky*

*If we push one end of the slinky forward and backward along its length, then two regions are formed. The region*



where the parts of the slinky are compressed together is called compression and it move towards right. While the region where the parts of slinky are stretched apart is called rarefaction and it also move towards right. In this way, longitudinal waves are produced in slinky, as shown in the figure.

**Q12: Clearly distinguish between transverse and longitudinal waves.** عرضی اور طولی موجوں میں فرق واضح کریں۔

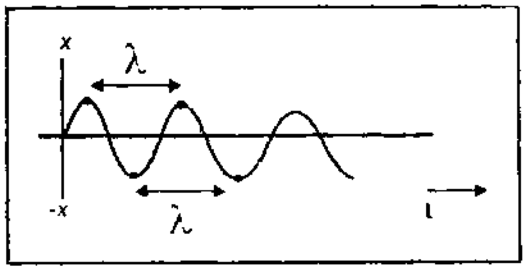
Ans. (BISE Swat, Peshawar, Kohat, Malakand 2019)

| Transverse Waves | Longitudinal Waves |
|---|---|
| 1) The disturbance occur perpendicular to the direction of motion of the wave. | 1) The disturbance occurs parallel to the direction of motion of the wave. |
| 2) Consists of crests and trough. | 2) Consists of compression and rarefaction. |
| 3) The distance between two nearest crests or two nearest troughs is equal to wavelength "λ". | 3) The distance between two nearest compressions or two rarefactions is equal to wavelength "λ". |
| 4) Water waves, waves produced in a stretched string are the examples of transverse waves. | 4) Sound waves, waves produced in a compressed spring are the examples of longitudinal waves. |

**Q13: Define the following terms: wavelength, frequency, time period, amplitude, velocity of waves**
مندرجہ ذیل اصطلاحات کی تعریف کریں: طول موج، فریکوئنسی، ٹائم پیریڈ، حیطہ اور موجوں کی ولاسٹی

Ans. (1) Wavelength (طولِ موج)

"The shortest distance between points where the wave pattern repeats itself is called wavelength". (OR)

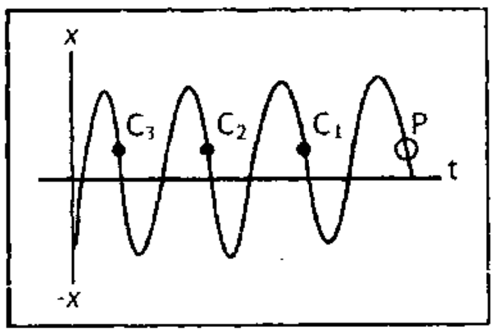



"The distance covered by a wave in one time period "T" is called wavelength".

The wavelength is represented by "λ". Its unit is meter.

2) Frequency (فریکوئنسی)

The number of wave cycles "N" passing through a certain point "P" in unit time "t" is called frequency i.e.




$$\boxed{f = \frac{N}{t}} \quad \text{______ (1)}$$

In the given figure, if the three cycles $C_1$, $C_2$ and $C_3$ cross point "P" in one second, then according to equation (1), frequency will be 3 hertz. i.e.

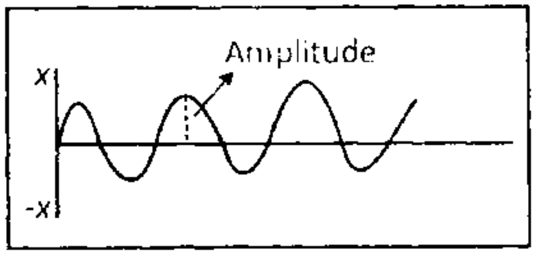
$$f = \frac{3}{1} = 3Hz \Rightarrow f = 3Hz$$

3) Time Period (ٹائم پیریڈ)

"The time required for one wave cycle to pass through a certain point is called time period. It is represented by "T". Its unit is second. The time period is equal to the reciprocal of frequency i.e.,

$$\boxed{T = \frac{1}{f}}$$

4) Amplitude (حیطہ)




The maximum displacement of a particle of the medium from its mean position is known as amplitude. It is represented by "$x_o$". Its unit is meter.

5) Speed of a wave

The distance travelled by a wave in a unit time is called speed of a wave. It is represented by "v". Its unit is "m/sec". The speed of the wave depends upon the nature of waves and medium of propagation.

**Q14: Prove the relation between wave speed, wavelength and frequency of wave. (OR) Show that, $v = f\lambda$**

موجوں کی سپیڈ، طول موج اور فریکوئنسی میں تعلق ظاہر کریں۔ یا ثابت کریں کہ $v = f\lambda$

Ans. We know that the speed is given

$$v = \frac{s}{t} \text{ ——— } (1)$$

In case of waves, we know that the distance covered by a wave in one time period "T" is equal to wavelength "λ". So we put $s = \lambda$ and $t = T$ in equation (1), so we get

$$v = \frac{\lambda}{T} \text{ ——— } (2)$$

We also know that, $T = \frac{1}{f}$ ——— (3)

Putting equation (3) in equation (2), we get

$$v = \frac{\lambda}{(1/f)} = \lambda \times \left(\frac{f}{1}\right) = \lambda \times f$$

$\Rightarrow$ $\boxed{v = f\lambda}$ ——— (4)

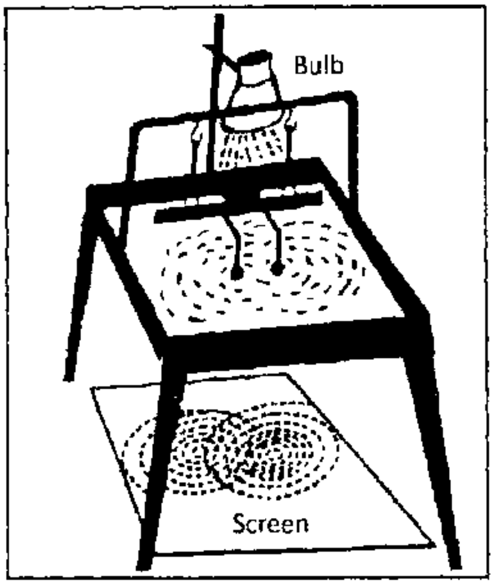
Equation (4) represents the relation between wave speed, frequency and wavelength of a wave.

**Q15: Using ripple tank explain reflection, refraction and diffraction of waves.** ریپل ٹینک کے ذریعے موجوں کی انعکاس، انعطاف اور انکساری خصوصیات کی وضاحت کریں۔

Ans. <u>Ripple Tank</u>

It is a device with the help of which we can study the various characteristics of water waves.

<u>Construction (ساخت)</u>



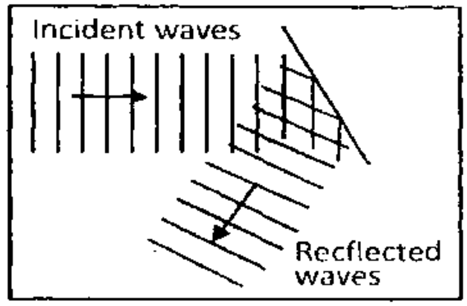

It consists of a rectangular tray containing water fitted with a glass bottom. A light bulb is fixed above the tray while a viewing screen is placed well below the tray.

Now when a disturbance is produced in water with the help of uniform rod, then transverse waves are produced. The pattern of the waves can be obtained on the screen with the help of parallel rays of light. The crests of the waves appear as bright bands while the trough appears as dark bands.

Using ripple tank, we can study the various properties of waves like reflection, refraction and diffraction.

### 1) Reflection of Waves (موجوں کا انعکاس)

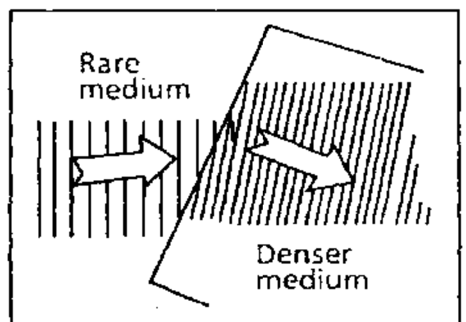
*When an obstacle is placed in the path of travelling waves, then the waves strike the obstacle and reflect through various angles. Such phenomenon is known as reflection of waves.*




*In ripple tank, the reflection of waves can be studied by placing an upright surface in water. The given figure indicates the reflection of waves from a flat surface.*

### 2) Refraction of Waves (موجوں کا انعطاف)

*When waves enters from a rare medium (لطیف واسطہ) into a denser medium (کثیف واسطہ), then the waves bends away slightly from its original path. Such phenomenon is known as refraction of waves.*



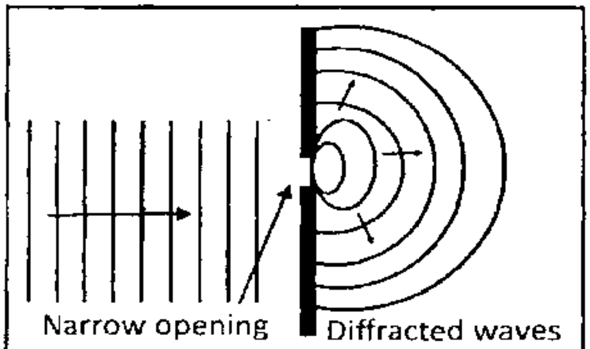

Refraction of waves

*In ripple tank, refraction of waves can be studied by placing a plastic sheet at the bottom of ripple tank. The waves will refract at the edges of plastic sheet. The speed of waves is greater in rare medium as compare to denser medium.*

### 3) Diffraction of Waves (موجوں کا انکسار)

*When waves passes through a narrow opening, then the waves spread out about the opening, such phenomenon is called diffraction of waves.*

In ripple tank, the diffraction of waves can be studied by placing two obstacles in such a way, that a small opening is left between them, as shown in the figure. The waves will diffract around the corners of the opening after passing through it.



*Diffraction of waves*

## Solution of Examples, Assignments

**Example 1: What is the frequency of oscillation if the time period is 20ms?**

Solution:

Given data:

Time period $= T = 20ms = 20\times10^{-3}s$ $\qquad [milli = 10^{-3}]$

Required: Frequency of oscillation $= f = ?$

Calculation: We know that, $f = \frac{1}{T}$ ______(1)

Putting the values in equation (1), we get

$$f = \frac{1}{T} = \left[\frac{1}{20\times10^{-3}}\right]Hz$$

$$\Rightarrow f = 0.05\times10^{3}Hz \Rightarrow \boxed{f = 50Hz}$$

$\boxed{f = 50Hz}$ Answer

**Assignment 1: When an object oscillates with a frequency of 0.5Hz, what is its time period?**

Solution:

Given data: Frequency $= f = 0.5Hz$

Required: Time period $= T = ?$

Calculation: We know that, $f = \frac{1}{T} \Rightarrow T = \frac{1}{f}$ ——— (1)

Putting the values in equation (1), we get

$T = \frac{1}{f} = \frac{1}{0 \cdot 5} = 2sec$

$\boxed{T = 2sec}$ Answer

> Example 2: A spring has a spring constant of 48·0N/m· This spring is pulled to a distance of 55cm from equilibrium· What is the restoring force?

Solution:

Given data: Displacement $= x = 55cm = 0 \cdot 55m$,

$k = 48 \cdot 0N / m$

Required: Restoring force $= F = ?$

Calculation: We know that, $F = -kx$ ——— (1)

Putting the values of equation (1), we get

$\Rightarrow F = -48 \cdot 0 \times 0 \cdot 55N \Rightarrow \boxed{F = -26 \cdot 4N}$

$\boxed{F = -26 \cdot 4N}$ Answer

> Assignment 2: Determine the restoring force of a spring displaced 1·5m, with the spring constant of 30·0N/m·

Solution:

Given data: Displacement $= x = 1 \cdot 5m$,

Spring constant $= K = 30 \cdot 0N / m$

Required: Restoring force $= F = ?$

Calculation: We know that, $F = -Kx$ ——— (1)

Putting the values of equation (1), we get

$F = -kx = -30 \cdot 0 \times 1 \cdot 5N \Rightarrow \boxed{F = -45N}$

$\boxed{F = -45N}$ Answer

**Example 3: What is the mass of a vertical mass-spring system if it oscillates with a period of 2·0sec and has a spring constant of 20·0N/m?**

Solution:

Given data: Time period = $T = 2.0sec$,

Spring constant = $K = 20.0N/m$

Required: Mass of vertical mass-spring system = $m = ?$

Calculation: We know that,

$$T = 2\pi\sqrt{\frac{m}{k}} \longrightarrow (1)$$

Squaring both sides of equation (1), we get,

$$T^2 = 4\pi^2\frac{m}{k} \Rightarrow m = \frac{T^2k}{4\pi^2} \text{———} (2)$$

Putting the values in equation (2), we get,

$$\Rightarrow m = \frac{(2)^2 \times 20}{\left[4 \times (3.14)^2\right]} \Rightarrow m = 2.02kg$$

$\boxed{m = 2kg}$ Answer

**Assignment 3: A body of mass 0·2kg is attached to a spring placed on a frictionless horizontal surface. The spring constant of spring is 4N/m. Find the time period of oscillating mass-spring system.**

Solution:

Given data: Mass = $m = 0.2kg$,

Spring constant = $K = 4N/m$

Required: Time period = $T = ?$

Calculation: We know that, $T = 2\pi\sqrt{m/k}$ ——— (1)

Putting the values of equation (1), we get

$$\Rightarrow T = 2 \times 3.14\sqrt{0.2/4} = 6.28 \times \sqrt{0.05}sec$$

$$\Rightarrow T = 6.28 \times 0.22sec \Rightarrow T = 1.38sec$$

$\boxed{T = 1.4sec}$ Answer

**Example 4:** Determine the magnitude of restoring force for a pendulum bob of mass 100·0gm that has been pulled to an angle of 10° from the vertical.

**Solution:**

Given data: Mass $= m = 100gm = 0{\cdot}1kg$

Acceleration due to gravity $= g = 9{\cdot}8m/sec^2$

Angle $= \theta = 10°$

Required: Restoring force $= F = ?$

Calculation: We know that, in case of simple pendulum, the component "$mg\sin\theta$" acts as restoring force, so we have,

$$F = -mg\sin\theta \text{ ——— } (1)$$

Putting the values of equation (1), we get

$$\Rightarrow F = -0{\cdot}1 \times 9{\cdot}8 \times \sin 10° = -0{\cdot}98 \times 0{\cdot}17N$$

$$\boxed{F = -0{\cdot}167N} \text{ Answer}$$

**Assignment 4:** At what angle must a pendulum be displaced to create a restoring force of 4·00N on a bob with a mass of 500gm?

**Solution:**

Given data: Restoring force $= F = 4{\cdot}00N$

Mass $= m = 500gm = 0{\cdot}5kg$

Required: Angle $= \theta = ?$

Calculation: We know that, in case of simple pendulum, the component "$mg\sin\theta$" acts as restoring force, so we get,

$$F = mg\sin\theta \Rightarrow \sin\theta = F/mg \text{ ——— } (1)$$

Putting the values of equation (1), we get

$$\Rightarrow \sin\theta = 4{\cdot}00/(0{\cdot}5 \times 9{\cdot}8) = 4{\cdot}00/4{\cdot}9 = 0{\cdot}816$$

$$\Rightarrow \sin\theta = 0{\cdot}816 \Rightarrow \theta = \sin^{-1}(0{\cdot}816) = 54{\cdot}6°$$

$$\boxed{\theta = 54{\cdot}6°} \text{ Answer}$$

*Example 5: What is the gravitational field strength on planet mercury, if a 0·500m pendulum swings with a period of 2·30sec?*

*Solution:*

*Given data:* Time period $= T = 2\cdot3sec$,

Length $= l = 0\cdot500m$

*Required:* Gravitational field strength $= g = ?$

*Calculation:* We know that, $T = 2\pi\sqrt{\frac{l}{g}}$ ——— (1)

Squaring both sides of equation (i), we get,

$$T^2 = 4\pi^2 l / g \Rightarrow g = \frac{4\pi^2 l}{T^2} \text{ ——— } (2)$$

Putting the values of equation (2), we get

$$\Rightarrow \quad g = \frac{4 \times (3\cdot14)^2 \times 0\cdot500}{(2\cdot3)^2} = \frac{19\cdot7}{5\cdot29} = 3\cdot73N/kg$$

$\boxed{g = 3\cdot73N/kg\ [down]}$ Answer

*Assignment 5: What is the gravitational field strength at the top of Mount Everest at an altitude of 8954·0m, if a pendulum with a length of 1·00m has a period of 2·01sec?*

*Solution:*

*Given data:* Length $= l = 1m$

Time period $= T = 2\cdot01sec$

*Required:* Gravitational field strength $= g = ?$

*Calculation:* We know that, $T = 2\pi\sqrt{\frac{l}{g}}$ ——— (1)

Squaring both sides of equation (1), we get,

$$T^2 = \frac{4\pi^2 l}{g} \Rightarrow g = \frac{4\pi r^2 l}{T^2} \text{ ——— } (2)$$

Putting the values of equation (2), we get

$$\Rightarrow \quad g = \frac{4 \times (3.14)^2 \times 1}{(2.01)^2} = \frac{39.4384}{4.0401} = 9.76 N/kg$$

$\boxed{g = 9.76 N/kg}$ Answer

**Example 6:** A student vibrates the end of a spring at 2.6Hz. this produces a wave with a wavelength of 0.37m. Calculate the speed of the wave.

Solution:

Given data: Frequency $= f = 2.6Hz$,

Wavelength $= \lambda = 0.37m$

Required: Speed of the wave $= v = ?$

Calculation: We know that, $v = f\lambda$ ——— (1)

Putting the values of equation (1), we get

$$v = f\lambda = 2.6 \times 0.37 m/sec$$

$$\Rightarrow \quad v = 0.962 m/sec$$

$\boxed{v = 0.962 m/sec}$ Answer

**Assignment 6:** A sound of wavelength $1.7x10^{-2}m$ Calculate the frequency of sound if its velocity is 343.4m/sec.

Solution: Given data: Wavelength $= \lambda = 1.7 \times 10^{-2} m$,

Speed of sound $= v = 343.4 m/s$

Required: Frequency $= f = ?$

Calculation: We know that,

$$v = f\lambda \quad \Rightarrow f = \frac{v}{\lambda} \text{ ——— } (1)$$

Putting the values of equation (1), we get

$$\Rightarrow \quad f = \frac{343.4}{(1.7 \times 10^{-2})} = \left[\frac{343.4 \times 10^2}{1.7}\right] Hz$$

$$\Rightarrow \quad f = 202.0 \times 10^2 Hz = 2.02 \times 10^4 Hz$$

$\Rightarrow \quad \boxed{f = 2.02 \times 10^4 Hz}$ Answer

## Exercise

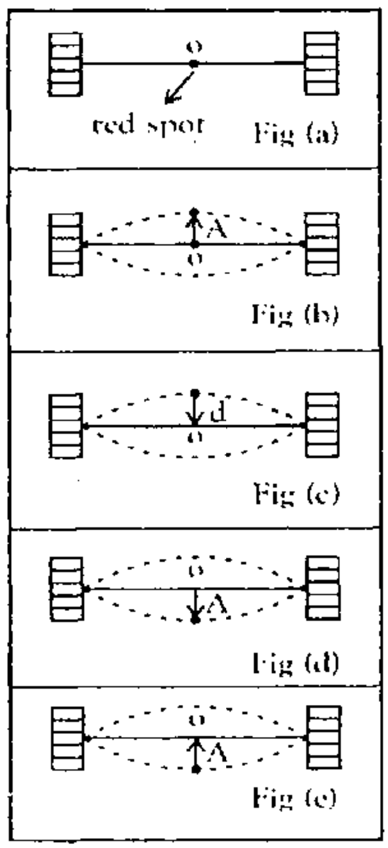
**Q1: Choose the correct answer.**

1. A transverse wave on a string has an amplitude A. A tiny spot on the string is colored red. As one cycle of the wave passes by, what is the total distance traveled by the red spot?

   a. A  b. 2A  c. $\frac{1}{2}A$  d. 4A✓

**Solution:**

Let the red spot is located at point "o" on the string as shown in the figure (a). Now when the string is made to vibrate, the spot move upwards with amplitude "A" as shown in the figure (b). Then the spot will move back towards mean position "o" by covering the distance "A" as shown in the figure (c). After reaching point "o", the spot will move downwards by covering distance "A" as shown in figure (d). Then the spot will move back towards mean position "o" as shown in figure (e).




In this way one cycle is complete. During this one cycle the total distance travelled by the red spot is given by,

$$\boxed{Total\ distance = A + A + A + A = 4A}$$

2. Which of the following does not affect the period of the mass-spring system?
   a. Mass b. Spring constant
   c. Amplitude of vibration✓
   d. All of the above affect the period

3. An object of mass 'm' oscillates on the end of a spring. To double the period, replaced the object with one of mass:
   a. 2m b. m/2 c. 4m✓ d. m/4

As $T = 2\pi\sqrt{\frac{m}{k}}$ ________(1)

For new mass, equation (1) becomes

$T' = 2\pi\sqrt{\frac{m'}{k}}$ ________ (2)

According to given condition, we have,

$T' = 2T$ __________(3)

$$\Rightarrow \quad 2\pi\sqrt{\frac{m'}{k}} = 2\left[2\pi\sqrt{\frac{m}{k}}\right]$$

$$\Rightarrow \quad \sqrt{\frac{m'}{k}} = 2\sqrt{\frac{m}{k}} \;\Rightarrow\; \frac{m'}{k} = 4\frac{m}{k}$$

$$\Rightarrow \quad \boxed{m' = 4m}$$

4. A car mounted on shock absorbers is like a mass on a spring. If we ignore damping, how will the frequency of the oscillations change if passengers (or a heavy load) are added to the car? The frequency will:
   a. Increase b. Decrease✓
   c. Stay the same d. Zero

Solution:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \text{ ________ } (1)$$

On increasing [i·e· load], the frequency will decrease· It is because, $f \propto \frac{1}{\sqrt{m}}$

5· If the pendulum completes exactly 12 cycles in 2·0min, what is the frequency of the pendulum?

a· 0·10Hz✓ b· 0·17Hz
c· 6·0Hz d· 10Hz

Solution:

Number of cycles=12

Time= 2min = 120sec

$$\text{Frequency} = \frac{\text{number of cycles}}{\text{time taken}} = \frac{12}{120}\text{Hz}$$

$\Rightarrow f = 0{\cdot}10\text{Hz}$

6· A certain pendulum has an iron bob· When the iron bob is replaced with lead bob of the same size, its time period will:

a· Stay the same✓ b· Decrease
c· Increase d· Be zero

Solution:

As $T = 2\pi\sqrt{\frac{l}{g}}$ ________ (1)

Equation (1) shows that time period of simple pendulum is independent of the mass· So value of "T" will be the same for both lead and iron bob·

7· A wave transports:

a· Energy but not matter✓
b· Matter but not energy
c· Both energy and matter d· Air

8· The bending of waves around the edges of the

obstacle is:

a. Reflection b. Refraction

c. Diffraction✓ d. Damping

## Conceptual Questions

Give a brief response to the following questions:

**Q1: Is every oscillatory motion is simple harmonic? Give examples.**

Ans. No, it is not necessary for an oscillatory motion to be simple harmonic.

Reasons and Explanation:

Case -1: If the restoring force is directly proportional to the displacement and always directed towards the mean postion i.e. $F \propto (-x)$, then such oscillatory motion will be simple harmonic.

Examples:

1. Oscillation of mass attached to an elastic spring.
2. Oscillation of bob of the simple pendulum.

Case -2: If the restoring force is not directly proportional to the displacement, then such oscillatory motion will not be simple harmonic.

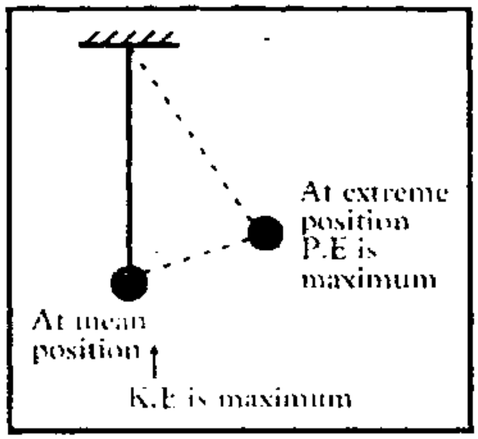
Example: When the recorder needle of the electrocardiogram oscillate with the heart beat, it is not simple harmonic.

**Q2: For a particle with a simple harmonic motion, at what point of the motion does the velocity attain the maximum magnitude, minimum magnitude?**

Ans. The velocity of the particle will be maximum at mean position and minimum at extreme position.

*Reasons and Explanation:*

When a particle executes simple harmonic motion, its energy may be converted from K·E into P·E and from P·E into K·E, but its total value remains the same·




*Case -1:* It mean position, the particle posses maximum K·E and minimum or zero P·E· Thus its velocity will be maximum at mean position·

$$\left[K\cdot E = \frac{1}{2}mv^2\right]$$

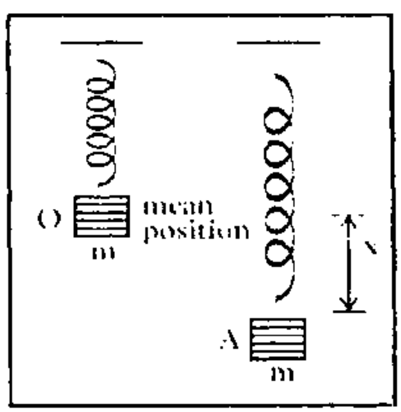
*Case -2:* At extreme position, the particle posses maximum P·E and minimum or zero K·E· Thus its velocity will be minimum at extreme position·

**Q3: Is the restoring force on a mass attached to spring in simple harmonic motion ever zero· If so where?**

Ans· Yes, the restoring force on a mass attached to spring in simple harmonic motion will be zero when the body reaches its mean position·

*Reasons and Explanation:*

Consider a body of mass "m" is attached to an elastic spring as shown in the figure· When the body is displaced from mean position "o" through a displacement "x", then restoring force "$F_{res}$"



exists due to elasticity of the spring. According to Hook's law, the magnitude of this force is given by,

$$F_{res} = -kx ________ (1)$$

Equation (1) shows that the restoring force increases as the displacement of the oscillating body increases, and decreases when the displacement of the body decreases. When the body reaches its mean position, it displacement becomes zero and as a result the restoring force on the body also becomes zero at mean position.

Putting $x = 0$ in equation (1), we get,

$$F_{res} = -k \times 0 \Rightarrow \boxed{F_{res} = 0}$$

Conclusion: The restoring force acting on oscillating body will become zero at mean position.

**Q4: If we shorten the string of a pendulum to half its original length, what is the affect on its time period and frequency?**

Ans. If we shorten the string of a pendulum to half its original length, its time period will decrease and frequency will increase.

Reasons and Explanation:

(a) Effect on time period:

We know that the time period of simple pendulum is given by,

$$T = 2\pi\sqrt{\frac{l}{g}} \text{ ---------- } (1)$$

Now if the length becomes half then we put $l = \frac{l}{2}$ in equation (1), we get

$$T' = 2\pi\sqrt{\frac{l}{2g}}$$

$$\Rightarrow \quad T' = \frac{1}{\sqrt{2}}\left[2\pi\sqrt{\frac{l}{g}}\right] \text{———} (2)$$

Putting equation (1) in equation (2), we get,

$$T' = \frac{T}{\sqrt{2}} \text{———} (3)$$

Equation (3) shows that the time period will decrease by a factor $\frac{1}{\sqrt{2}}$ when the length of the string becomes half.

(b) Effect on frequency:

We know that

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}} \text{———} (4)$$

Put $l = \frac{l}{2}$ in equation (4), we get,

$$f' = \frac{1}{2\pi}\sqrt{\frac{g}{\left(\frac{l}{2}\right)}} \Rightarrow f' = \frac{1}{2\pi}\sqrt{\frac{2g}{l}}$$

$$\Rightarrow \quad f' = \sqrt{2}\left[\frac{1}{2\pi}\sqrt{\frac{g}{l}}\right] \text{———} (5)$$

Putting equation (4) in equation (5), we get,

$$f' = \sqrt{2}f \text{———} (6)$$

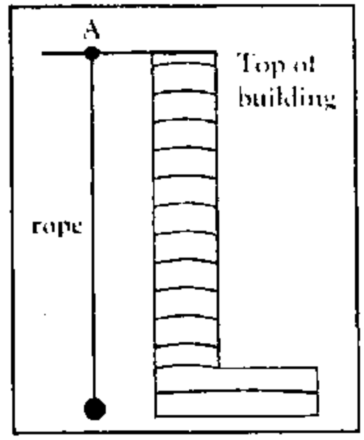
Equation (6) shows that frequency of simple pendulum will increase by a factor $\sqrt{2}$ when the length of the string becomes half.

**Q5: A thin rope hangs from dark high tower so that its upper end is not visible. How can the length of the rope be determined?**

Ans. We can determined the length of the rope by connecting a bob to the lower end of the rope so

that the arrangement becomes a simple pendulum.

Reasons and Explanation:



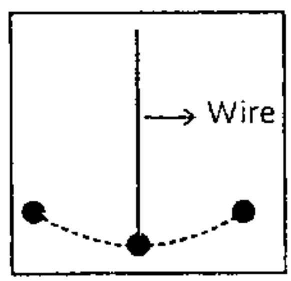

Consider a rope of length "l" hangs from the top of a building at point "A" as shown in the figure.

Attached a small piece of stone to the lower end of the wire, so that the arrangement becomes like a simple pendulum.

Now we know that the time period of simple pendulum is given by,

$$T = 2\pi\sqrt{\frac{l}{g}} \text{ ——— } (1)$$

Squaring both sides of equation (1), we get,




$$T^2 = 4\pi^2\left[\sqrt{\frac{l}{g}}\right]^2$$

$$\Rightarrow \quad T^2 = 4\pi^2\frac{l}{g} \Rightarrow 4\pi^2 l = gT^2$$

$$\Rightarrow \quad l = \frac{gT^2}{4\pi^2} \text{ ——— } (2)$$

Now set pendulum into vibration and note the time for one vibration which gives us the time period "T".

Now put the values of "g", "T" and "π" in equation (2), the length of the wire can be calculated.

| |
|---|
| Q6. Suppose you stand on a swing instead of sitting on it. Will your frequency of oscillation increases or decreases? |

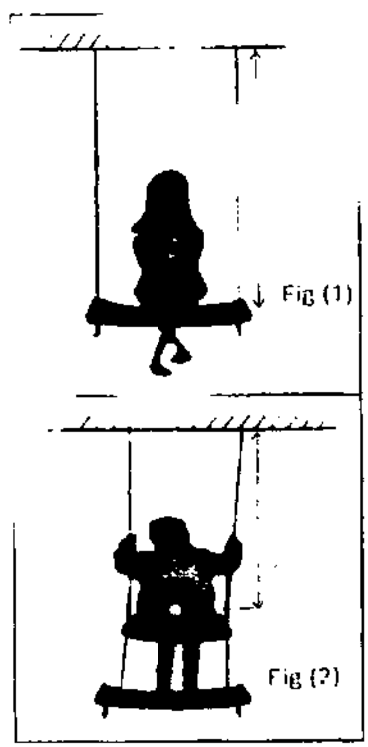
Ans. When we stand on a swing instead of sitting

on it, our frequency of oscillation will increase.

Reasons and Explanation:

Ans. The swing may be considered as a simple pendulum. In this case the frequency of oscillation is given by,

$$f = \frac{1}{2\pi}\sqrt{\frac{g}{l}} \text{ ———— (1)}$$




Where, $l$ = length the pendulum (swing) and is equal to the distance from the point of suspension to the centre of gravity (Navel) [ناف] of the person on the swing.

This length decreases as the person stands up on the swing, i.e. centre of gravity (Navel) of the person rises up. Using equation (1), it is clear that frequency of oscillation is inversely proportional to the square root of length of the pendulum. So, frequency of oscillation increases as length decreases when the person stands up instead of sitting.

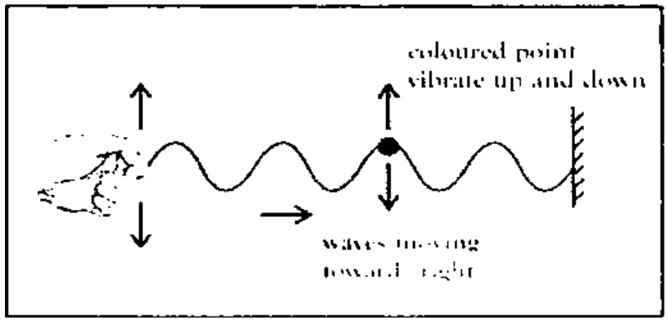
**Q7: Explain the difference between the speed of a transverse wave travelling along a cord and the speed of a tiny coloured part of the cord?**

Ans. The speed of a transverse wave travelling along a cord and the speed of a tiny coloured part of the cord will be the same. The only difference is that the tiny coloured part of the cord will oscil-

late perpendicularly to the direction of propagation of the wave.

**Reasons and Explanation:**

Consider a cord having a coloured tiny part as shown in the figure. Let its one end is fixed



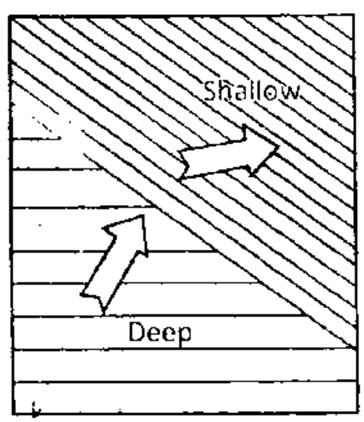

and other end is hold in our hand. Now if we move the cord up and down, the transverse waves are produced in the cord. These waves travels along the cord from left to right with certain speed "v" as shown in the figure. When these waves passes through the coloured part of the cord, the coloured part move up and down with same speed "v". The only difference is that the waves moves with velocity "v" from left to right while the coloured part move up and down with same speed "v" about their mean position.

**Q8: Why waves refract at the boundary of shallow and deep water?**

Ans. Waves refracts at the boundary of shallow and deep water due to change in speed and wavelength of waves.

**Reasons and Explanation:**

Refraction of waves involves a change in the direction of waves as they pass from one medium to another. In refraction, both speed and wave-



length of waves change. The speed of a wave depends upon the properties of a medium through which it travels. The speed of waves is not the same in shallow water and deep water. Waves travel fast in deep water.

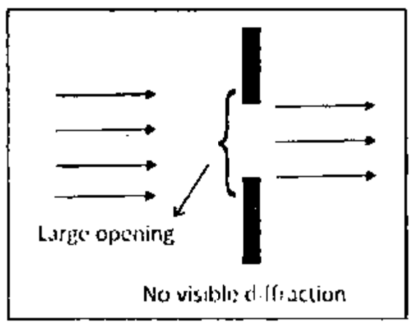
Thus, if water waves are passing from deep water into shallow water, they slow down. Thus the speed of waves decreases their wavelength also changes. As a result the wave changes its direction i.e. refracted.

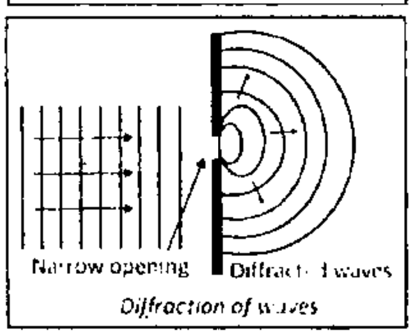
**Q9: What is the effect on diffraction if the opening is made small?**

Ans. If the opening is made small, then the waves will be diffracted easily.

Reasons and Explanation:

The condition for the diffraction of the wave is that the width of the opening should be comparable to the wavelength of the waves.



Diffraction of waves

Case -1: If the width of the opening is large as compared to the wavelength of wave then wave will pass straight through the opening and will not be diffracted.

Case -2: If the width of the opening is allowed to decrease such that it becomes comparable to the wavelength of the given wave, then the wave will bend around the opening. These waves then spread out and produce diffraction pattern.

## Comprehensive Questions

*Given an extended response to the following questions:*

**1. What is simple harmonic motion (S.H.M)? What are the conditions for an object to oscillate with S.H.M?**

Ans. See answer of question no 5 in the text.

**2. Show that the mass-spring system executes simple harmonic motion (S.H.M).**

Ans. See answer of question no 6 in the text.

**3. What is simple pendulum? Diagrammatically show the forces acting on simple pendulum. Also show that simple pendulum executes simple harmonic motion.**

Ans. See answer of question no 7 in the text.

**4. What is wave motion? How wave can be categorized?**

Ans. See answer of question no 9 in the text.

**5. How waves transport energy without carrying the material medium? Also describe the connection between oscillatory motion and waves.**

Ans. See answer of question no 10 in the text.

**6. Prove the relation between wave speed, wavelength and frequency of wave.**

Ans. See answer of question no 14 in the text.

**7. Using ripple tank explain reflection, refraction and diffraction of waves.**

Ans. See answer of question no 15 in the text.

## Numerical Questions

**Q1: A mass hung from a spring vibrates 15 times in 12s. Calculate (a) the frequency and (b) the period of the vibration.**

Solution:

Given data:

Number of vibration $= N = 15$

Time for 15 vibrations $= t = 12sec$

Required:

(i) Frequency $= f = ?$

(ii) Time period $= T = ?$

Calculation: (i) Frequency $= f = \frac{N}{t}$ ——(1)

Putting the values in equation (1), we get

$\Rightarrow \quad f = \left(\frac{15}{12}\right)Hz \qquad f = 1.25Hz$

(ii) We know that

$$T = \frac{1}{f} = \left(\frac{1}{1.25}\right)sec$$

$\Rightarrow \quad T = 0.8sec$

Answer:

(i) frequency $= f = 1.25Hz$

(ii) Time period $= T = 0.8sec$

**Q2: A spring requires a force of 100.0N to compress it to a displacement of 4cm. What is its spring constant?**

Solution:

Given data:

Force $= F = 100N$,

Displacement $= x = 4cm = 0.04m$

Required:

Spring constant $= K = ?$

Calculation:

We know that,

$$F = Kx \Rightarrow K = \frac{F}{x} \text{------} (1)$$

Putting the values of "F" and "x" in equation (1), we get,

$$K = \left(\frac{100}{0.04}\right)\frac{N}{m} = 2500.0\frac{N}{m}$$

$$\Rightarrow K = 2.5 \times 10^3 \frac{N}{m}$$

Answer: $\boxed{\text{Spring constant} = K = 2.5 \times 10^3 \frac{N}{m}}$

**Q3: A second pendulum is a pendulum with period of 2.0s. How long must a second pendulum be on the earth ($g = 9.81 m/s^2$) and Moon (where $g = 1.62 m/s^2$)? What is the frequency of second pendulum at earth and on moon?**

Solution:

Given data:

Time period of second pendulum $= T = 2sec$,

Acceleration due to gravity on earth

$= g_e = 9.8 m/sec^2$

Acceleration due to gravity on moon

$= g_m = 1.62 m/sec^2$

Required: (i) Length of pendulum at earth $= l_e = ?$

(ii) Length of pendulum on moon $= \ell_m = ?$

(iii) Frequency at earth $= f_e = ?$

(iv) Frequency at moon $= f_m = ?$

Calculation: (i) We know that,

$$T = 2\pi\sqrt{\frac{\ell}{g}} \quad \text{———} \quad (1)$$

Squaring both sides, we get,

$$T^2 = 4\pi^2\frac{\ell}{g} \Rightarrow \ell = \frac{gT^2}{4\pi^2} \Rightarrow \ell_e = \frac{g_e T^2}{4\pi^2} \quad \text{———} \quad (2)$$

Putting the values in equation (2), we get,

$$\ell_e = \left[\frac{9\cdot8\times2^2}{4\times(3\cdot14)^2}\right]m = \left(\frac{39\cdot2}{39\cdot4384}\right)m = 0\cdot99m$$

$\Rightarrow$ $\boxed{\ell_e = 0\cdot99m}$

(ii) For moon, we replaced "$\ell$" by "$\ell_m$" and "$g_e$" by "$g_m$" in equation (ii), we get,

$$\ell_m = \frac{g_m T^2}{4\pi^2} \quad \text{———} \quad (3)$$

Putting the values in equation (3), we get,

$$\ell_m = \left[\frac{1\cdot62\times2^2}{4\times(3\cdot14)^2}\right]m = \left[\frac{6\cdot48}{39\cdot4384}\right]m$$

$\Rightarrow$ $\boxed{\ell_m = 0\cdot16m}$

(iii) The frequency of pendulum is given by,

$$f_e = \frac{1}{2\pi}\sqrt{\frac{g}{\ell_e}} \quad \text{———} \quad (4)$$

Putting the values in equation (4), we get,

$$f_e = \left[\frac{1}{2\times3\cdot14}\sqrt{\frac{9\cdot8}{0\cdot99}}\right]Hz = \left[\frac{1}{6\cdot28}\sqrt{9\cdot9}\right]Hz$$

$$\Rightarrow \quad f_e = \left(\frac{3\cdot146}{6\cdot28}\right)Hz = 0\cdot50Hz$$

$\Rightarrow \boxed{f_e = 0.5Hz}$

(iv) The frequency at moon is given by,

$$f_m = \frac{1}{2\pi}\sqrt{\frac{g_m}{l_m}} \text{ ——— } (5)$$

Putting the values in equation (5), we get,

$$f_m = \frac{1}{2\times 3.14}\sqrt{\frac{1.62}{0.16}} = \frac{1}{6.28}\sqrt{10.125} = \frac{3.18}{6.28}$$

$\Rightarrow \boxed{f_m = 0.50Hz}$

Answers:

(i) Length of pendulum on earth = $l_e = 0.99m$

(ii) Length of pendulum on moon = $l_m = 0.16m$

(iii) Frequency of pendulum on earth = $f_e = 0.5Hz$

(iv) Frequency of pendulum on moon = $f_m = 0.5Hz$

**Q4: Calculate the period and frequency of a propeller on a plane if it completes 250 cycles in 5.0s.**

Solution:

Given data:

Number of cycles = $N = 250$ cycles

Time for 250 cycles = $t = 5sec$

Required:

(i) Frequency = $f = ?$

(ii) Time period = $T = ?$

Calculation:

(i) We know that, $f = \frac{N}{t}$ ——— (1)

Putting the values of equation (1), we get

$$f = \frac{N}{t} = \frac{250}{5sec} cycles = 50 \quad cycles/sec$$

$$\Rightarrow \quad \boxed{f = 50Hz} \qquad [Cycles / sec = Hz]$$

(ii) As $T = \frac{1}{f} = \left(\frac{1}{50}\right) sec$

$$\Rightarrow \quad \boxed{T = 0.02sec}$$

Answers:

$\boxed{(i)\ Frequency = f = 50Hz}$

$\boxed{(ii)\ Time\ period = T = 0.02sec}$

**Q5: Water waves with wavelength 2·8m, produced in a ripple tank, travel with a speed of 3·80m/s. What is the frequency of the straight vibrator that produced them?**

Solution:

Given data:

Wavelength of water waves $= \lambda = 2.8m$

Speed of waves $= v = 3.80m/sec$

Required:

Frequency of waves $= f = ?$

Calculation: We know that,

$$v = f\lambda \Rightarrow f = \frac{v}{\lambda} \longrightarrow (i)$$

Putting the values in equation (i), we get,

$$f = \left(\frac{3.80}{2.8}\right) Hz = 1.36Hz = 1.4Hz$$

$$\Rightarrow \quad \boxed{f = 1.4Hz}$$

$\boxed{Frequency\ of\ waves = f = 1.4Hz}$ Answer

**Q6: The distance between successive crests in a series of water waves is 4·0m, and the crests travel 9·0m in 4·5s· What is the frequency of the waves?**

*Solution:*

*Given data:* Distance between two successive crests = wavelength $= \lambda = 4m$

Distance covered $= s = 9m$

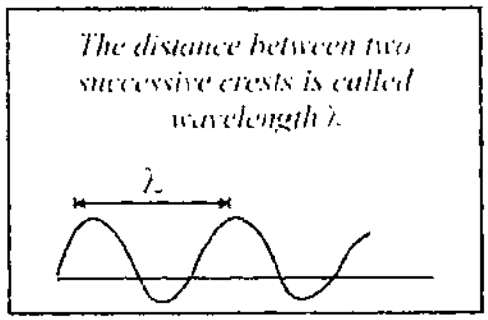
Time taken for

$$9m = t = 4{\cdot}5sec$$

Speed of wave

$$= v = \frac{s}{t} = \left(\frac{9}{4{\cdot}5}\right)\frac{m}{sec}$$

$$\Rightarrow \quad v = \frac{2m}{sec}$$




*Required:*

Frequency of waves $= f = ?$

*Calculation:*

We know that,

$$v = f\lambda \quad \Rightarrow f = \frac{v}{\lambda} \longrightarrow (i)$$

Putting the values in equation (i), we get,

$$f = \left(\frac{2}{4}\right)Hz = 0{\cdot}5Hz$$

$\boxed{\text{Frequency of waves} = f = 0{\cdot}5Hz}$ Answer

**Q7: A station broadcasts an AM radio wave whose frequency is 1230 x $10^3$Hz (1230 KHz on the dial) and an FM radio wave whose frequency is 91·9 x $10^6$Hz (91·6 MHz on the dial)· Find the dis-**

tance between adjacent crests in each wave.

Solution:

Given data:

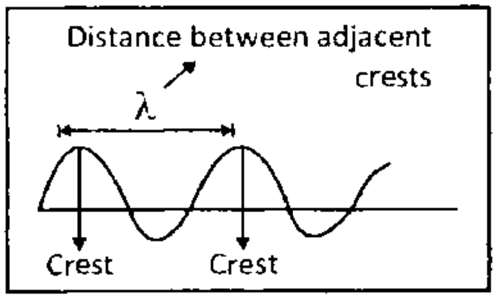
Frequency of AM radio waves $= f_{AM} = 1230 \times 10^3 Hz$

Frequency of FM radio waves $= f_{FM} = 91.9 \times 10^6 Hz$

Speed of radio waves $= v = c = 3 \times 10^8 m/sec$

Required: Distance between adjacent crests in each case = ?

We know that the distance between adjacent crests is equal to the wavelength, so we need to calculate the wavelength in each case i.e.,




(i) Wavelength of AM radio waves $= \lambda_{AM} = ?$

(ii) Wavelength of FM radio waves $= \lambda_{FM} = ?$

Calculation:

(i) We know that,

$$v = f\lambda \Rightarrow c = f_{AM}\lambda_{AM}$$

$$\Rightarrow \quad \lambda_{AM} = \frac{c}{f_{AM}} \text{ ——— } (1)$$

Putting the values in equation (1), we get,

$$\lambda_{AM} = \left[\frac{3 \times 10^8}{1230 \times 10^3}\right] m = 2.44 \times 10^2 m$$

$$\Rightarrow \quad \boxed{\lambda_{AM} = 244.0m}$$

(ii) For FM waves, equation (1) can be written as,

$$\lambda_{FM} = \frac{c}{f_{FM}} \text{ ——— } (2)$$

Putting the values in equation (2), we get,

$$\lambda_{FM} = \left[\frac{3\times10^8}{91\cdot9\times10^6}\right]m = 0\cdot0326\times10^2\,m$$

$$\Rightarrow \boxed{\lambda_{FM} = 3\cdot26m}$$

**Answers:**

$$\boxed{\text{(i) Wavelength of AM radio waves} = \lambda_{AM} = 244m}$$

$$\boxed{\text{(ii) Wavelength of FM radio waves} = \lambda_{FM} = 3\cdot26m}$$

❍❍❍

CHAPTER

# 11 SOUND

**Q1: What is sound? How it is produced, transmitted and received?**
**آواز سے کیا مراد ہے؟ یہ کیسی پیدا ہوتی ہے؟ کیسی اشاعت کرتی ہے؟ اور کیسے ہمیں سنائی دیتی ہے؟**

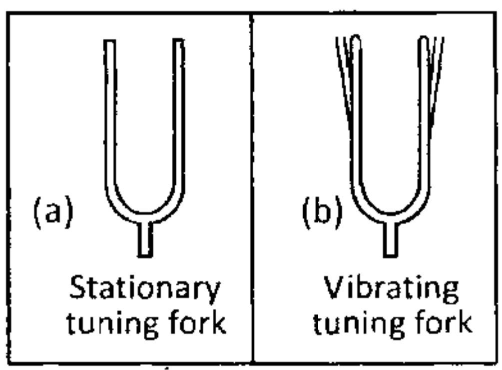
Ans. Sound

"The sensation felt by our ears is known as sound."

Explanation [وضاحت]

Sound is a form of energy. The sound can travels through a medium in the form of longitudinal waves [طولی موجیں]. When the sound falls on the membrane of our ear it produces the sensation of hearing.

1) Generation (or) Production of Sound Waves [آواز کی موجوں کی پیدائش]




The sound waves can be heard due to vibration of a body. For example, a tuning fork is a device which is used in laboratory for producing sound. It has two prongs [شاخیں]. When a tuning fork is strike on a rubber pad, the prongs begins to vibrate and a special sound is produced. We can feel the vibration of prongs by touching them with hands.

2) <u>Propagation of Sound Waves (or) Transmitting Medium</u>

When a body begins to vibrate, then it produces a disturbance [خلل] in the surrounding medium [واسطہ] due to which the energy is transmitted to the neatest particle of the medium. These particles of the medium also start vibration and transfer their energy to their neighboring particles. Thus these neighboring particles also start vibrations.

In this way, the energy of vibrations propagates through the medium from the source to the receiving end.

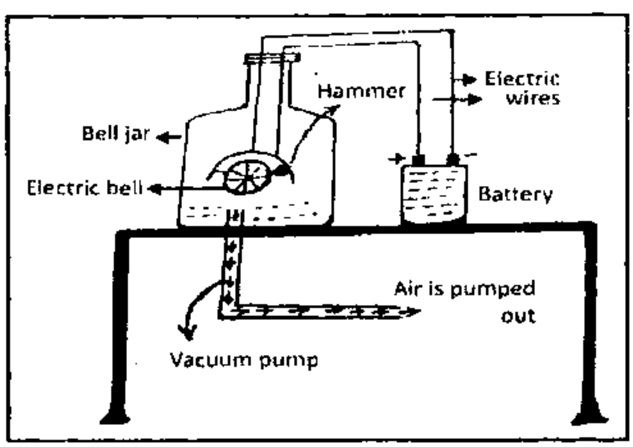
3) <u>Hearing (or) Receiving of Sound Waves (OR) Hearing Device</u>

When sound waves fall on the ear or any hearing device, the energy of sound waves set the membrane of the ear or device into vibrations. The vibration of source and vibrations of membrane possesses the same characteristics, so the listener [سننے والا] hears the sound.

**Q2: Show experimentally that sound waves cannot passes through vacuum?**

تجربے کے ذریعے ثابت کریں کہ آواز خلاء سے نہیں گزر سکتی۔

Ans. Sound waves needs a material medium for their propagation. It cannot passes through vacuum. It can be proved



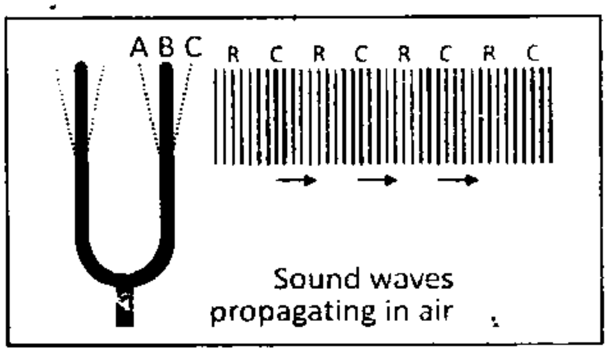
*with the help of following experiment.*

*Experiment*

*Consider a bell jar placed on a table as shown in the figure. There is an electric bell inside the jar. The bell is connected to an electric circuit as shown in the figure. In the beginning, air is present inside the jar. Now when we close the circuit, the hammer hits the bell due to which sound is produced. The sound propagates through air inside the jar and finally reaches our air and thus we hear the sound. Now it we pumped out the air from the jar gradually with the help of vacuum pump, the intensity of sound decreases. Finally no sound can be heard when air is totally pumped out from the jar. At this stage there is vacuum inside the jar through which sound waves cannot pass and thus we hear no sound.*

*Q3: Discuss the propagation of sound waves through air.* ہوا میں آواز کی اشاعت پر بحث کریں۔

*Ans. Consider a tuning fork as shown in the figure.*




*When we strike the tuning fork on a rubber pad, it starts vibrations. In given figure, the point 'B' represents the original position of right prong. While point 'A' and 'C' represents the extreme positions [انتہائی مقام] of*

right prong during vibrations.

When the prong moves towards right, the air is compressed and thus a compression is produced which transmits in the air towards right.

Similarly, when the prong moves towards left, a rarefaction is produced which transmit trough the air.

In this way, the compressions and rarefactions are produced regularly due to the vibrations of tuning fork. As a result, the sound waves pass through air in the form of longitudinal waves.

**Q4: Define loudness of sound. On which factors, the loudness of sound depends?**

آواز کی بلندی سے کیا مراد ہے؟ اس کا انحصار کن باتوں پر ہے؟

Ans. Loudness of Sound [آواز کی بلندی]

(BISE Swat, Mardan 2019)

"The magnitude of auditory sensation [سماعتی احساس] produced by sound is known as loudness of sound".

Explanation (وضاحت)

The loudness of sound enables us to distinguish between a faint [دھیمی] and loud sound. The loudness of sound depends upon the following factors:

1) Area of Vibrating Body [مرتعش جسم کا رقبہ]

The loudness of sound depends upon the area of vibrating body. The loudness of sound will be greater if the area of vibrating body is greater and vice versa.

For example, the area of school bell is larger than the area of a house bell, so the loudness of school bell is greater than the loudness of a house bell.

Similarly, the area of a dhool [drum] is larger than

the area of a dhoolac [small drum], so the loudness of a dhool is greater than the loudness of dhoolac.

2) Amplitude of Vibrating Body [مرتعش جسم کا حیطہ]

The loudness of sound also depends upon the amplitude of vibrating body. If the amplitude of vibration is greater, then larger will be the loudness of sound and vice versa.

For example, if we struck the membrane of a dhool strong, we hear a loud sound. It is because when we struck the membrane strong, then the membrane vibrates with larger amplitude and as a result we hear a loud sound.

3) Distance from Vibrating Body [مرتعش جسم سے فاصلہ]

The loudness of sound also depends upon the distance from vibrating body. If the distance between the source and listener decreases, then loudness of sound increases. If the distance between the source and listener increases, then the loudness of sound decreases.

**Q5: Define and explain intensity of sound waves.**
آواز کی شدت کی تعریف اور وضاحت کریں۔

Ans. Definition: (BISE Swat, Mardan 2019)

"The amount of sound energy which passes normally [عموداً] through a unit area of the surface in a unit time is known as the intensity of sound waves".

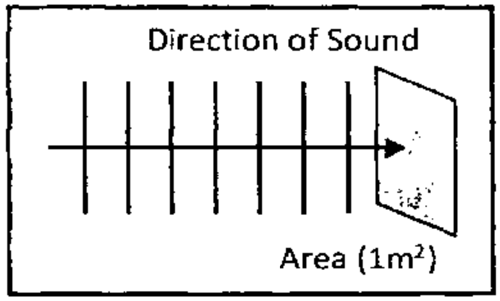
Explanation (وضاحت)

If "A' is the area of the surface, "E" is the amount of sound energy to be transferred in time "t", then intensity

$$Intensity = \frac{E}{(A \times t)}$$

$$\Rightarrow \boxed{I = \frac{E}{(A \times t)}} \text{———} (1)$$

Equation (1) shows that the intensity of sound depends upon the amount of sound energy, area of the surface and time interval "t".




The intensity will be greater for larger value of "E" and smaller values of "A" and "t".

<u>Unit of Intensity</u>

As $I = \frac{E}{(A \times t)}$

$[E = 1\ joule, A = 1m^2, t = 1sec]$

$$\Rightarrow I = \frac{1\ Joule}{(1m^2 \times 1sec)}$$

$$\Rightarrow I = \frac{watt}{m^2} = watt \cdot m^{-2}$$

$$\left[\frac{J}{sec} = watt\right.$$

So the unit of intensity is

"$\frac{watt}{m^2}$" (or) "$watt \cdot m^{-2}$"

**Q6: Discuss the relation between intensity of sound and loudness of sound. (OR) Discuss Weber Fechner law.** آواز کی شدت اور بلندی میں کیا تعلق ہے؟ یا ویبر فیچنر کے قانون کو بیان کریں۔

Ans. According to Weber Fechner law, the loudness of sound is directly proportional to the logarithm

of intensity is:

$$L \propto \log I \Rightarrow \boxed{L = K\log I} \text{———} (1)$$

Equation (1) represents the mathematical form of Weber Fechner law. This equation gives us the relation between loudness of sound and intensity of sound. In equation (1), "K" is constant of proportionality and its value depends upon the system of units.

**Q7: Define and explain intensity level (or) Sound level.** آواز کی شدت کے لیول سے کیا مراد ہے؟ اس کی اکائی بیان کریں۔

Ans. <u>Intensity Level (or) Sound Level</u>

"The difference between the loudness of two sounds where one sound is faintest audible, is known as intensity level (or) sound level".

Let "$L_o$" be the loudness of faintest audible sound and "L" be the loudness of any other sound, then

$$L_o = K\log I_o \text{———} (1)$$

And $L = K\log I$ ——— (2)

Now for finding the intensity level, we subtract equation (1) from equation (2), we get,

$$L - L_o = K\log I - K\log I_o$$

$$\Rightarrow \text{Intensity level} = K[\log I - \log I_o]$$

$$\Rightarrow \text{Intensity level} = K\log\left(\frac{I}{I_o}\right)$$

$$\Rightarrow \text{Intensity level} = K\log\left(\frac{I}{I_o}\right) \text{———} (3)$$

> $\log a - \log b = \log[a/b]$
> Bel, decibel are Units of intensity Level.
> 1 bel = 10 decibel

Put $K = 1$, so equation (3) $\Rightarrow$

$$\boxed{I.L = \log\left(\frac{I}{I_o}\right) \text{ bels}} \text{———} (4)$$

In terms of decibel, equation (4) can be written as,

$$\boxed{I{\cdot}L = 10\log(I/I_o) \text{ decibel}} \text{ ——— } (5)$$

Using equation (5), we can construct a scale for measuring the intensity level of sound. Such scale is known as "decibel scale'.

**Q8: Define and explain the pitch of sound with examples.** آواز کی پچ سے کیا مراد ہے؟ مثالوں سے وضاحت کریں۔

**Ans. Pitch of Sound**

"The characteristics of sound by which a shrill sound [باریک آواز] can be distinguish [فرق کرنا] from a grave sound [بھاری آواز] is known as pitch of sound".

**Explanation (وضاحت)**

The pitch of sound depends upon the frequency of sound. The pitch will be high if the frequency is high and the pitch will be low if the frequency is also low. The sound produced by dogs, donkeys, frogs and men are grave sound, because they have low pitch. While the sound produced by women, rates and cats etc are shrill sound because they have high pitch.

**Logarithm Intensity Levels and Sound Intensity**

| Intensity level (dB) | Intensity level (B) | Intensity ($pW/m^2$) |
|---|---|---|
| 0 | 0 | 1 |
| 10 | 1 | 10 |
| 20 | 2 | 100 |
| 30 | 3 | 1000 |
| 50 | 5 | 100000 |
| 100 | 10 | 10000000000 |

| Logarithm Intensity Levels and Sound Intensity | | |
|---|---|---|
| Source | Intensity level (dB) | Intensity ($W/m^2$) |
| Threshold or hearing | 0 | $10^{-12}$ |
| Normal breathing | 10 | $10^{-11}$ |
| Average whisper at 2m | 20 | $10^{-10}$ |
| Empty theatre | 30 | $10^{-9}$ |
| Residential area at night | 40 | $10^{-8}$ |
| Quiet restaurant | 50 | $10^{-7}$ |
| Two-person conversation | 60 | $10^{-6}$ |
| Busy street traffic | 70 | $10^{5}$ |
| Vacuum cleaner | 80 | 10[illegible] |
| Loud stereo in average room | 90 | 10[illegible] |
| Maximum level in concert hall (13th row) | 100 | 10[illegible] |
| Pneumatic chisel | 110 | $10^{-1}$ |
| Maximum level at some rock concerts | 120 | $10^{0}$ |
| Propeller plane taking off | 130 | 10 |
| Threshold of pain | 140 | 10[illegible] |
| Military jet taking off | 150 | $10^{+3}$ |
| Wind tunnel | 160 | $10^{+4}$ |
| Instant perforation of the eardrum | 170 | $10^{+5}$ |

**Q9: Define and explain quality of sound.**

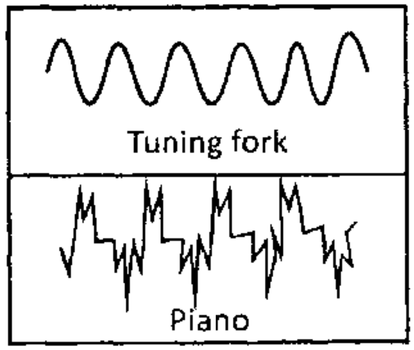
آواز کی وصف کی تعریف کریں اور وضاحت کریں۔

Ans. "The property of sound by which two sounds of same loudness and pitch are distinguished from

each other is known as quality of sound".

Explanation (وضاحت)

With the help of quality of sound, we can distinguished between sound of one instrument from the sound of another instrument, although they have the same pitch and loudness. In given figure, the wave form by tuning fork and piano are shown. Both piano and tuning fork have the same pitch and loudness but their wave forms are different. So their quality is different and they can be distinguished from each other. Similarly, with the help of quality, we can recognize [پہچان کرنا] a person speaking in the dark or standing behind the wall etc.




**Q10: What is noise pollution? Discuss the harmful effects of noise pollution. (OR) Why noise is a nuisance? Explain.**

شور کی آلودگی پر بحث کریں۔(یا) شور تکلیف دہ کیوں ہوتی ہے؟وضاحت کریں۔

Ans. Noise Pollution

"The excessive displeasing [ناخوشگوار] sound which disrupts the activity of human, animals and plants in the environment is called noise pollution".

Explanation (وضاحت)

There are many sources which causes noise pollution. For example, the horn of vehicles, the machinery used in construction, the machinery used in

industry, the low flying aircrafts and their sonic booms, loud speakers, wood cutting machines, metal work, proximity of railway stations etc can cause noise pollution.

Noise is a nuisance because of its harmful effects on human beings, animals, plants and other inert things in the environment. Some of the harmful effects of noise pollution are given below:

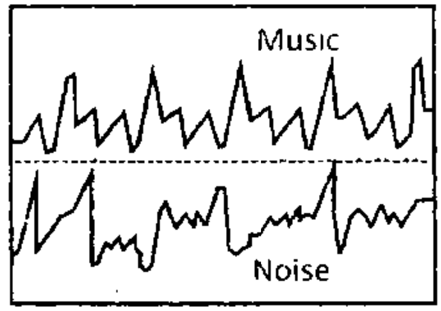
1. Noise pollution causes temporary or permanent deafness [بہراپن].
2. It reduces the working efficiency.
3. It interferes with communication.
4. It increases the rate of errors which causes accidents.
5. It reduces the ability to read and write.
6. It reduces the learning and understanding capabilities of human being.
7. It causes dangerous diseases like blood pressure, heart problems and mental illness.
8. It damages the nervous system of animals.
9. It decreases the productivity of animal.
10. It effects the normal growth of the plants.
11. It effect the high buildings, bridges etc because the noise creates waves which can put them in danger condition.

| |
|---|
| Q11: Explain musical sound and noise.<br>موسیقائی آواز اور شور کی وضاحت کریں۔ |

Ans. 1) <u>Musical Sound (موسیقائی آواز)</u>

(BISE Malakand 2019)

"The sound which produces a pleasing sensation in




the ear is called musical sound. The musical sound is composed of regular and uniform vibrations. It proceeds at regular intervals and there is no sudden change in its loudness. The wave form produced by sitar, piano, violin, tuning fork etc are the examples of musical sound.

2) Noise (شور)

"The sound which produces a displeasing sensation in the ear is called noise. The noise sound is composed of irregular intervals and there is sudden change in its loudness, as shown in the figure.

The sound of donkeys, sound of explosion, roar of street traffic, horn of vehicles etc are the examples of noise.

**Q12: Write a note on speed of sound waves.**
آواز کی موجوں کی رفتار پر نوٹ تحریر کریں۔

Ans. Speed of Sound Waves: (BISE Peshawar + Kohat)

The speed of sound is the distance traveled per unit time by a sound wave as it propagates through a medium.

Explanation (وضاحت)

The speed of sound depends on the material through which it is passing. The sound waves can pass through solids, liquids and gases. The sound waves can pass through solids with greater speed as compare to liquids and gases. The values of speed of sound waves for different materials are given in the table.

The speed of sound can be calculated by dividing the distance covered by the sound waves in time "t". i.e.

Speed of sound = distance / time

$$\Rightarrow \boxed{v = \frac{s}{t}}$$

| The Speed of Sound | | |
|---|---|---|
| **State** | **Material** | **Speed at 0°C (m/s)** |
| Solid | Aluminum | 5104 |
| | Glass | 5050 |
| | Steel | 5050 |
| | Maple wood | 4110 |
| | Bone (human) | 4040 |
| | Pine wood | 3320 |
| Solid/Liquid | Brain | 1530 |
| Liquid | Fresh water | 1493 (at 25°C) |
| | Sea water | 1470 |
| | Alcohol | 1241 |
| Gas (at atmospheric pressure) | Hydrogen | 1270 |
| | Helium | 970 |
| | Nitrogen | 350 (at 20°C) |
| | Air | 332 |
| | Oxygen | 317 |
| | Carbon dioxide | 258 |

**Q13: Discuss the speed of sound in air.**
ہوا میں آواز کی رفتار پر بحث کریں۔

Ans. <u>Speed of Sound in Air [ہوا میں آواز کی رفتار]:</u>
(BISE Kohat, Swat 2019)

The speed of sound in air is inversely proportional to the square root of the density of air. i.e.

$$v \propto \frac{1}{\sqrt{\delta}} \longrightarrow (i) \qquad [\delta \text{ represents the density}]$$

While the speed of sound in air is directly proportional to the square root of absolute temperature. i.e.

$$v \propto \sqrt{T} \longrightarrow (ii)$$

Now when the temperature of air increases, its density decreases and as a result the speed of sound increases. The speed of sound in dry air at 0°C is 331m/sec. The speed of sound in increases by 0.6m/s for each 1°C rise in temperature. Now for a certain temperature "T", the speed of sound in air can be written as,

$$\boxed{v = 331 + 0.6T} \longrightarrow (iii)$$

Using equation (iii), we can calculate the speed of sound in air for given value of "T". For example, if the temperature of air is 20°C, then we put $T = 20°C$ in equation (iii), so we get,

$$v = [331 + 0.6 \times 20]\ m/sec$$

$$\Rightarrow \quad v = (331 + 12) m/sec \Rightarrow \boxed{v = 343 m/sec}$$

Thus the speed of sound in air will be 343m/sec at 20°C. If we put $T = 30°C$, then equation (iii) becomes,

$$v = [331 + 0.6 \times 30] m/sec$$

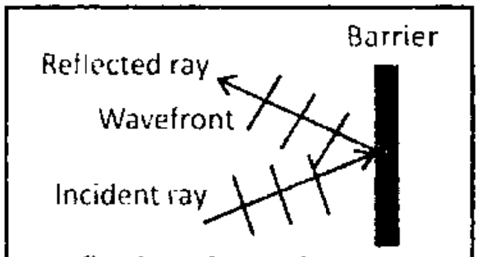
$$\Rightarrow \quad v = (331 + 18) m/sec \Rightarrow \boxed{v = 349 m/sec}$$

Thus at a temperature of 30°C, the speed of sound in air will be 349m/sec.

**Q14: Explain the reflection of sound waves.**
آواز کی انعکاس کی وضاحت کریں۔

Ans. **Reflection of Sound Waves [آواز کی انعکاس]**

"The bouncing back of sound waves from a hard surface is called reflection of sound."



Reflection of Sound

**Explanation (وضاحت)**

The sound waves can reflect from any hard surface. For example, it can reflect from walls, metal sheet, plywood etc easily.

**Applications of Reflection of Sound**

1. The reflection of sound is used in megaphone.
2. The reflection of sound is used in sound boards.
3. The reflection of sound is used in ear trumpet.
4. The reflection of sound is used to determine the depth of the sea.
5. The reflection of sound is used by insects for safe journey during night.
6. The reflection of sound causes the phenomenon of echo and reverberation.
7. The reflection of sound is used for range and direction finding.
8. The reflection of sound is used for scanning and cleaning purposes.

**Q15: What is an echo? How it can be avoided in the halls?** گونج سے کیا مراد ہے؟ہالوں میں اس کی روک تھام کیسی ممکن ہے؟

Ans. **Echo [گونج]**

"The repetition of a sound by reflection of sound

waves from a surface is known as echo."

Explanation (وضاحت)

When a person shouts in a big empty hall, we first hear his original sound. After a little while, we hear the reflected sound of the shout. This reflected sound is an echo. Thus when we hear an echo, we are actually hearing a reflected sound. Thus an echo is simply a reflected sound.

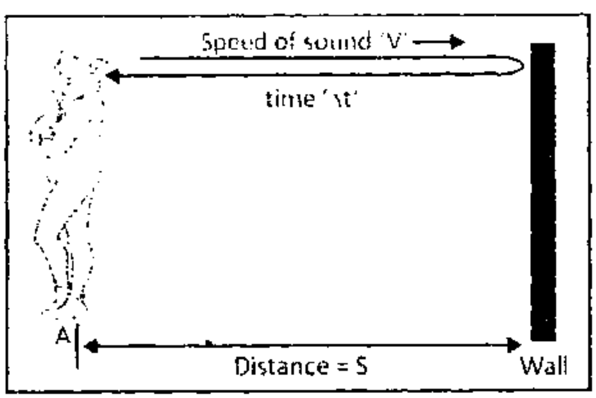
When we shout at a wall from 344 meters away, the sound takes 1 second to reach the wall. The sound reflects from the wall and takes 1 second to return. So we hear the echo after two seconds we have shouted.

The phenomenon of echo can be avoided by using sound absorbing materials and by avoiding curved surfaces.

**Q16: Calculate the minimum distance for echo to be heard.** گونج سننے کے لیے کم سے کم فاصلہ معلوم کریں۔

Ans. Consider Muskan is standing at point "A" at a distance "S" from the wall as shown in the figure.

Let sound wave travels from point "A" towards the wall by covering a distance "S" as shown in the figure. The sound reflects from the wall and travels back toward Muskan. So the total distance covered by the sound waves is given by,



Distance covered = S + S = 2S

Let "$\Delta t$" represents the time in which the sound travels the distance "2S". Let "v" represents the speed of sound, then

$$v = \frac{\text{Distance covered}}{\text{Time}} = \frac{2S}{\Delta t}$$

$$\Rightarrow \quad v = \frac{2S}{\Delta t} \quad \Rightarrow \quad S = \frac{v \cdot \Delta t}{2} \text{ ——— } (1)$$

Now at room temperature i.e., 20°C, we put

$v = 343 m/sec$ and $\Delta t = 0.1 sec$ in equation (1),

so we get, $S = \left(\frac{343 \times 0.1}{2}\right) m \Rightarrow \boxed{S = 17.15m}$

So the minimum distance for echo to be heard is 17.15m.

**Q17: Define and explain acoustic and acoustic protection.**

Ans. (1) Acoustic

"The study of production, propagation and properties of sounds as well as the application of the results of scientific study of sound in the design of buildings, halls, rooms etc is called acoustic."

Explanation (وضاحت)

The halls or big rooms which are built on the basis of acoustic, the sound can be heard clearly everywhere in these places. But if these places are built without the application of acoustic, then a loud sound will be heard at some spots and low sound will be heard at other spots in these places.

(2) Acoustic Protection

"There are some factors which effect the clear cut

hearing of sound in big halls and rooms. The elimination of such factors from the halls and rooms is called acoustic protection."

**Explanation (وضاحت)**

The factors which affect the acoustic of rooms and halls are given below:

a) **Echo:** The reflection of sound from the hard surface is called an echo. Due to echo, the original sound cannot be heard clearly. The echo can be avoid by using sound absorbing materials in the walls of the halls and rooms.

b) **Reverberation [آواز کا دہرا پن]:** "The presence of sound after the sounding source has stopped is known as reverberation." The reverberation causes a general confusion of the sound impressions on the ear. To avoid such problems, we should use sound absorbing things like carpet, curtains [پردے] and cushions in the halls and rooms.

c) **Focusing of Sound at certain Spots [مخصوص جگہوں پر آواز کا فوکس ہونا]:** The curved wall causes the sound waves to be focused at certain spots. Due to this problem, the sound at other places cannot be heard clearly. To avoid this problem, we should construct flat walls instead of curved walls.

**Q18: Write a note on audible frequency range.**
سماعت پذیر صوتی فریکوئنسی کی رینج پر نوٹ لکھیں۔

**Ans.** The human ear can hear only those sounds whose frequency is between 20Hz and 20000Hz. We cannot hear the sound whose frequency is above

20000Hz, because the membrane of our ear cannot vibrate with such high frequencies. Similarly, we cannot hear the sound whose frequency is below 20Hz, because loudness of such sound is very low to be heard.

a) Infrasonic Sound (زیر صوتی آواز)

The sound whose frequency is less than 20Hz is called infrasonic sound. The sound produced by whales, elephants and rhinoceroses are infrasonic.

b) Ultrasonic Sound (بالا صوتی آواز)

The sound whose frequency is above 20000Hz is known as ultrasonic sound. These are very powerful waves and can be used in medical, scientific and industrial fields for various purposes.

**Q19: Discuss the applications of ultrasonics.**
**الٹراسانک (بالا صوتی آواز) کی عملی اطلاقات بیان کریں۔**

Ans. Ultrasonic sounds are those waves whose frequency is above 20000Hz. These are powerful waves and can be used for the following purposes:

a) Breaking of Kidney's Stone (گردوں میں پتھری کا توڑنا)

The ultrasonic machines are used for breaking of kidney stones. For this purpose, the ultrasonic waves are focused on the stone in the kidney due to which the stone breaks into pieces. These pieces are then excreted through urinary track. This method is safer and effective than open surgery.

b) Checking of an Unborn Baby (نازائیدہ بچے کی چیکنگ)

The ultrasonic waves are used to check an unborn baby in the womb [بچہ دانی] of mother. For this purpose, an ultrasonic transmitter is moved over the

mother's body. The ultrasonic waves which are reflected from different layers inside the body are picks up by a detector. The signals are then focused on the screen and we can see its final image.

c) Quality Control

The ultrasonic detectors are used in mills for controlling the uniformity of thickness of the metallic sheet.

d) Material Testing

The ultrasonic detectors are used to detect cracks and holes in high quality materials. For this purpose, a beam of ultrasonic is allowed to pass through the material. These waves reflect from cracks and holes and thus the damage portion of the material can be detected.

e) Ultrasonic Cleaning (الٹراساؤنڈ کے ذریعے صفائی)

The ultrasonics are used for cleaning of machinery and instruments. These waves are also used for the scaling of teeth. The dirty is removed due to vibrations of ultrasonic waves.

f) Ultrasound is used in the treatment of muscular pain and joints diseases.

g) Ultrasound is used for finding the level of a liquid in a metal tank without opening it.

h) Sonar (سونار)

It is a device with the help of which we can detect the submarines [آبدوز] submerged [زیرِ آب] in water. The sonar is also used for finding the schools [غول] of fish in water.

The sonar uses sound waves with the help of which

we can also determine the depth of the sea [سمندر].
For this purpose, the ultrasonic pulse is sent from the bottom of the ship to bed of the sea. The pulse reflects from the sea bed and reaches back to the ship. The time of travelling "t" of the pulse noted.
As the speed of sound through sea water is 1450m/sec, so the depth of the sea can be determine by using the following formula:

Depth of sea = vt

## Solution of Examples, Assignments

**Example 1: Show that if one sound is twice as intense as another. About what factor is the sound level in [dB] higher?**

Solution:

Given data: Intensity of one sound $= I_1 = I$

Intensity of 2nd sound $= I_2 = 2I_1 = 2I$

Required: Sound level $= I.L = ?$

Calculation: We know that the intensity level or sound level is given by, $I.L = 10\log\left(\frac{I_2}{I_1}\right)$ ——— (1)

Putting the values of equation (1), we get

$$I.L = 10\log\left(\frac{I_2}{I_1}\right) = 10\log\left(\frac{2I}{I}\right)$$

$$\Rightarrow I.L = 10\log(2) = 10 \times 0.301 = 3.01 = 3.01dB$$

$I.L = 3.01dB$ Answer

*Assignment 1: Suppose that when a certain sound intensity level [in dB] triples, the sound intensity [in w/m²] also triples. Determine this sound intensity level.*

*Solution:*

*Given data:* $I = 3I_o$

*Required:* Intensity level $= I.L = ?$

*Calculation:* Since

$$I.L = 10\log\left(\frac{I}{I_o}\right) \text{------} (1)$$

Putting the values in equation (1), we get

$$I.L = 10\log\left(\frac{3I_o}{I_o}\right)$$

$$= 10\log(3) = 10 \times 0.477$$

$$\boxed{4.77db}$$ Answer

*Example 2: You are standing at 1.5km from the cannon with a stop watch. You start the stop-watch when you see the cannon flash and stop it when the sound is heard. The time recorded on your stopwatch is 4.4sec, what is the speed of sound? What is this speed in km/hr?*

*Solution:*

*Given data:* Distance $= S = 1.5km$

$\Rightarrow \quad S = 1.5 \times 1000m = 1500m$

Time $= t = 4.4sec$

*Required:* Speed of sound $= v = ?$

*Calculation:*

We know that, $s = vt \Rightarrow v = \frac{s}{t}$ ———— (1)

Putting the values in equation (1), we get

$$v = \frac{S}{t} = \left(\frac{1500}{4\cdot4}\right) m/$$

$$\boxed{v = 341 m/sec}$$

*Calculation in km/hr:*

To convert 341m/sec into "km/hr", we multiply it by "3600" and divide by "1000", so we get

$$v = 341 m/sec = \left(\frac{341 \times 3600}{1000}\right) km/hr$$

$$\Rightarrow \quad v = 1227\cdot6 km/hr$$

$$\boxed{v = 1228 km/hr}$$ Answer

**Assignment 2:** If the time between seeing lightning and hearing the thunder is 5·0sec· The speed of sound is 343m/sec· How far away is the lightening?

*Solution:*

*Given data:* Time $= t = 5\cdot0 sec$,

Speed of sound $= v = 343 m/sec$

*Required:* Distance of lightening $= S = ?$

*Calculation:* We know that, $s = vt$ ——— (1)

Putting the values in equation (1), we get

$$S = vt = (343 \times 5\cdot0) m = 1715\cdot0 m$$

$$\Rightarrow \quad S = 1\cdot715 km$$

$$\boxed{S = 1\cdot7 km}$$ Answer

**Example 3:** What is the wavelength of the sound in dry air if its frequency is 590Hz on a hot day with temperature of 40°C?

*Solution:*

*Given data:* Frequency of sound $= f = 590 Hz$,

Temperature $= T = 40°C$

*Requ* ... *sec waves v = λ340.9m/s*

*Calcu* ... *he speed of sound in terms of te...* ... *Answer*

$(v = 331 + 0.6T)$ ——— (1)

*Putting* $T = 40°C$ *in equation (1), we get,*

$v = (331 + 0.6 \times 40)m/sec = (331 + 24)m/sec$

$\Rightarrow$ $\boxed{v = 355m/sec}$

*Now for finding the wavelength, we have*

$v = f\lambda \Rightarrow \lambda = \dfrac{v}{f}$ ——— (2)

*Putting the values of "v" and "f" in equation (2), we get,*

$\lambda = \left(\dfrac{355}{590}\right)m = 0.60m$

$\boxed{\lambda = 0.6m}$ *Answer*

> *Assignment 3: What is the frequency of sound with wavelength 0.25m in air with temperature of 32°C?*

*Solution:*

*Given data:* *Wavelength of sound waves* $= \lambda = 0.25m$

*Temperature* $= T = 32°C$

*Required:* *Frequency of sound waves* $= f = ?$

*Calculation:* *We know that. the speed of sound waves in terms of temperature is given by,*

$v = (331 + 0.6T)$ ——— (1)

*Putting* $T = 32°C$ *in equation (1), we get,*

$v = (331 + 0.6 \times 32)m/sec = (331 + 19.2)m/sec$

$\Rightarrow v = 350.2m/sec \Rightarrow \boxed{v = 350m/sec}$

*Now for finding the frequency of sound waves, we have,*

$$v = f\lambda \quad \Rightarrow \quad f = \frac{v}{\lambda} \text{ ——— } (2)$$

Putting the values of "v" and "λ" in equation (2), we get,

$$f = \left(\frac{350}{0.25}\right)Hz \quad \Rightarrow \boxed{f = 1400Hz}$$

$\boxed{f = 1400Hz}$ Answer

**Example 4:** During a winter school camp on Pipe Line Track from Donga Gali to Ayubia, Aalia shouts at a cliff and hears her echo after 1.5s. She record the temperature on her personal thermometer as 3°C. How far is the cliff from her?

Solution:

Given data: Time $= \Delta t = 1.5sec$,

Temperature $= T = 3°C$

Required: Distance of cliff from Aalia $= S = ?$

Calculation: For echo phenomenon, we have,

$$v = \frac{2S}{\Delta t} \Rightarrow S = \frac{v \cdot \Delta t}{2} \text{ ——— } (1)$$

We know that

$$v = (331 + 0.6T) \text{ ——— } (2)$$

Put $T = 3°C$ in equation (2), we get,

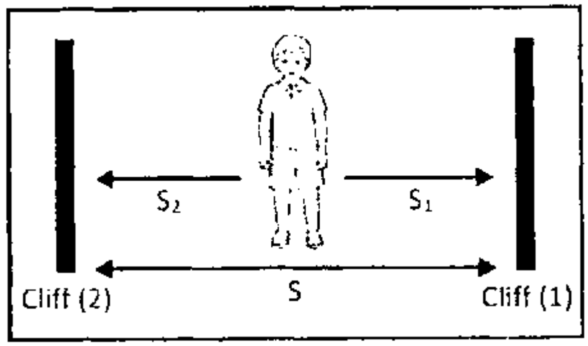
$$v = (331 + 0.6 \times 3)m/sec = (331 + 1.8)m/sec = 332.8m/sec$$

Putting the values of "v" and "Δt" in equation (1), we get,

$$S = \left(\frac{332.8 \times 1.5}{2}\right)m \Rightarrow S = 249.6m = 250m$$

$\boxed{S = 250m}$ Answer

*Assignment 4: A man stands in between two parallel cliffs and fires a gun, he hears two successive echoes after 3s and 5s. What is the distance between cliffs? Take speed of sound in air as 330m/sec.*




*Solution:*

*Given data:* Time for 1st echo

$= \Delta t_1 = 3sec,$

Time for 2nd echo

$= \Delta t_2 = 5sec,$

Let "$S_1$" be the distance between man and 1st cliff and "$S_2$" be the distance between man and 2nd cliff. Velocity of sound $= v = 330m/sec$

*Required:* Distance between the two cliffs = S =?

*Calculation:* (i) First we calculate the distance "$S_1$" between man and 1st cliff, for which we have,

$$S_1 = \frac{v \cdot \Delta t_1}{2} \text{ ——— } (1)$$

Putting the values in equation (1), we get

$$S_1 = \frac{v \cdot \Delta t_1}{2} = \left(\frac{330 \times 3}{2}\right)m = 495m$$

$$\Rightarrow \quad S_1 = 495m$$

(ii) Now we calculate the distance "$S_2$" between man and 2nd cliff, for which we have,

$$S_2 = \frac{v \cdot \Delta t_2}{2} \text{ ——— } (2)$$

Putting the values in equation (2), we get

$$S_2 = \frac{v \cdot \Delta t_2}{2} = \left(\frac{330 \times 5}{2}\right)m = 825m$$

$\Rightarrow \quad S_2 = 825m$

Now the distance between the two cliffs is given by,

$S = S_1 + S_2 = (495 + 825)m = 1320m$

$\boxed{S = 1320m}$ Answer

## Exercise

Q1: Choose the correct answer.

1. The intensity of a sound wave increases by $1000W/m^2$. What is this increase equal to in decibels?

   a. 10 b. 20 c. 30✓ d. 40

**Solution:**

$I_1 = I, \; I_2 = 1000I$

The change in intensity level of two sound having intensity "$I_1$" and "$I_2$" is given by,

$\Delta\beta = 10\log\left(\frac{I_2}{I_1}\right) \Rightarrow \Delta\beta = 10\log\left(\frac{1000I}{I}\right)$

$\Rightarrow \quad \Delta\beta = 10\log(1000) = 10 \times 3.0 \Rightarrow \boxed{\Delta\beta = 30\,dB}$

2. An echo occurs when a sound wave is......

   a. Absorbed b. Transmitted

   c. Refracted d. Reflected✓

3. Compared with a sound of 60 decibels, a sound of 80 decibels has an intensity.......times greater.

   a. 10 b. 100 c. 1000 d. 10000

**Solution:**

$\beta_1 = 60$ decibels, $\beta_2 = 80$ decibels

The change in intensity level of two sound having intensity "$I_1$" and "$I_2$" is given by,

$$\Delta\beta = 10\log\left(\frac{I_1}{I_2}\right) \Rightarrow \beta_2 - \beta_1 = 10\log\left(\frac{I_1}{I_2}\right)$$

$$\Rightarrow 80 - 60 = 10\log\left(\frac{I_1}{I_2}\right) \Rightarrow 20 = 10\log\left(\frac{I_1}{I_2}\right) \quad \text{___(1)}$$

Taking antilog of equation (1), we get,

$$\frac{I_1}{I_2} = (10)^2 = 100 \Rightarrow \boxed{\frac{I_1}{I_2} = 100}$$

4. The loudness of a sound is most closely related to its.........
   a. Frequency  b. Period
   c. Wavelength  d. Amplitude✓
5. Various instruments sound different even when they play the same note due to difference in...
   a. Pitch  b. Loudness
   a. Quality✓  d. Intensity
6. Humans can hear sound that is:
   a. Less than 20Hz
   b. Between 20Hz & 20KHz✓
   c. Greater than 20KHz
   d None
7. The speed of sound on a warm day when the outdoor temperature is 38°C is......
   a. 331m/s  b. 345m/s
   c. 354m/s✓  d. 362m/s

Solution:

$t = 38°C, v_o = 331 m/sec$

$v = v_o + 0.61 \times t$ ____ (1)

$\Rightarrow v = 331 + 0.61 \times 38 \Rightarrow \boxed{v = 354 m/sec}$

8. Minimum echo distance is reduced in:
   a. Summer  b. Winter✓

c. Spring d. Space

9. Which of the following cannot transmit sound?
a. Solid b. Liquid
c. Gas d. Vacuum✓

## Conceptual Questions

Give a brief response to the following questions:

**Q1. Why sound produced by a simple pendulum is not heard?**

Ans. The membrane of human ear can be vibrated by those sounds whose frequency is greater than 20Hz and below than 20,000Hz. In other words, we can say that we hears those sounds whose frequency is above 20Hz and below 20,000Hz.

Now we know that, the frequency of waves produced by a simple pendulum is below 20Hz, so such waves cannot vibrate the membrane of our ear and thus we cannot hear such sound.

**Q2. If a ringing bicycle bell is help tightly by hand, it stops producing sound, why?**

Ans. A ringing bicycle bell produces sound due to vibrations. Now if we held the ringing bell tightly by hand, then its vibrations will die out [i.e. becomes stop] and as a result the bell will produce no sound.

**Q3. Why is the intensity of an echo less than that of the original sound?**

Ans. When sound waves strike the surface of a wall or other objects, it reflects and move back in op-

posite direction. Such reflected sound wave represents the echo.

When the sound strikes with wall, it imparts some of its energy to the wall. Thus the reflected wave posses less energy and becomes less intense. Therefore, the intensity of an echo [reflected wave] is less intense than the original sound waves.

**Q4. In which medium air or water, an echo is heard sooner? Why?**

Ans. The speed of sound depends upon the elasticity of the medium. i.e. more the medium is elastic, greater will be the speed of sound and vice versa. Now the water is more elastic than air, so the sound waves will travel faster in water. That is why, we heard an echo sooner in water as compare to air.

**Q5. Why sound cannot be heard on the moon?**

Ans. Sound waves are longitudinal waves [mechanical waves] which needs a material medium for their propagation. As there is no material medium in the atmosphere of moon through which sound waves can pass. Thus a sound cannot be heard on moon.

**Q6. If a person places his ear on rails of railroad for determination of coming train, why is this done, and how does it work?**

Ans. We can hear the sound of a coming train by placing ear on the railway track even if it is quite far away. This is because sound waves travel very fast in solids than in gases (air). At STP [standard

temperature and pressure] the speed of sound in air is 332m/sec, while in steel (railway track) it is about 5100m/sec, i.e. 15 times faster. Thus by placing ear on the rails of railroads, a person may easily hear the sound of an approaching train long before he sees it.

**Q7. When you watch a thunderstorm, you see the lightning first, and you hear the thunder afterward. Why is the thunder delayed?**

Ans. Generally, lightening flash and the associated thunder occur at the same time in a thunderstorm. We, on the ground see lightening flash before hearing the thunder because light travels much faster than sound in air. The speed of light is about $3\times10^8$ m per second in air while that of sound is 340m/sec.

Thus, the reason we see lightening before we hear thunder is because of the fact that light travels much faster than sound.

**Q8. If the speed of sound is dependent on frequency, would music from marching band be enjoyed?**

Ans. The speed of sound is the distance travelled by sound waves per unit time as it propagates through an elastic medium. The speed of sound in an ideal gas depends only on temperature and properties of the medium.

One of the more important properties of sound is that, its speed is nearly independent of frequency. This independence is certainly true in open air for sounds in the audible range of 20Hz to 20000Hz.

If this independence were not true, we would certainly notice it for music played by a marching band i.e. high frequency sound swill travel faster than low - frequency sounds. And, it will not be possible for us to enjoy the music played by a marching band.

**Q9. Why does your voice sound fuller in the shower?**

Ans. Most showers are made up of tiles or other hard non-absorbent surfaces. The multiple reflections from these walls enrich the sound and making one's voice louder and more powerful.

Secondly, there is reverberation effect also. It occurs when our ear picks many echo's in a very short interval of time. This reverberation makes the singing sound richer and fuller.

Thirdly, there occurs resonance as well. It occurs when the frequency of sound wave being produced matches the frequency of the shower. Under such condition resonance occur and as a result we hear loud sound. Due to these effects, the sound in a shower is fuller and richer.

**Q10. Why is it so quiet after a snowfall?**

Ans. Snow is porous and is a good sound absorber. When snow accumulates on the ground, it acts as a sound absorber, damping sound waves like other sound absorbing materials. Snow wrap everything in a thick blanket, which acts as a sound barrier. A very little sound energy is reflected when sound waves hit against the snow surface. And due to its

porous nature, sound waves enter into its surfaces and make multiple reflections, due to which a considerable amount of sound energy is absorbed. Thus there is so quiet after a snowfall.

## Comprehensive Questions

Given an extended response to the following questions:

**1. What is sound? How it is produced, transmitted and received?**

Ans. See answer of question no 1 in the text.

**2. What is audible frequency range?**

Ans. See answer of question no 18 in the text.

**3. What is the speed of sound?**

Ans. See answer of question no 12 in the text.

**4. Describe the terms loudness, pitch and quality. Explain each by giving an example.**

Ans. See answer of question no 4, 8, 9 in the text.

**5. What is intensity level? Describe the decibels scale for the intensity of different sound levels.**

Ans. See answer of question no 7 in the text.

**6. What is noise? Explain why noise is nuisance?**

Ans. See answer of question no 10 in the text.

**7. How sound is reflected? Describe the difference between echo and reverberation.**

Ans. See answer of question no 14, 15 in the text.

**8. What is acoustic protection? Why is it important?**

Ans. See answer of question no 17 in the text.

## Numerical Questions

**Q1: The sound intensity 3m from a jackhammer is $8.20 \times 10^{-2} W/m^2$. What is the sound intensity level in decibels? (Use the usual reference level of $I_o = 1.00 \times 10^{-12} W/m^2$)**

**Solution:**

**Given data:** Intensity of sound $= I = 8.2 \times 10^{-2} W/m^2$

Usually reference level of $I_o = 1.0 \times 10^{-12} W/m^2$

**Required:** Intensity level $= I.L = ?$

**Calculation:** We know that

$$I.L = 10\log\left(\frac{I}{I_o}\right) \text{ ——— } (1)$$

Putting the values in equation (1), we get,

$$I.L = 10\log\left(\frac{8.2\times10^{-2}}{1.0\times10^{-12}}\right) = 10\log\left(8.2\times10^{10}\right)$$

$\Rightarrow \quad I.L = 10 \times \log(82000000000)$

$\Rightarrow \quad I.L = 10 \times 10.91381385\ dB = 109.138\ dB$

$\Rightarrow \quad I.L = 109.14\ dB$

$\boxed{\text{Intensity level} = I.L = 109.14\ dB}$ Answer

**Q2: A ship is anchored where the depth of water is 120m. An ultrasonic signal sent to the bottom of the lake returns in 0.16s. What is the speed of sound in water?**

**Solution:**

**Given data:** Depth of water $= s = 120m$

Total time $= T = 0.16 sec$

Time taken by the sound to reach the bottom of water

$$= t = \frac{T}{2} \Rightarrow t = \frac{0.16}{2} sec = 0.08 sec$$

Required: Speed of sound $= v = ?$

Calculation: We know that

$$S = vt \Rightarrow v = \frac{S}{t} \text{——— (1)}$$

Putting the values in equation (1), we get,

$$v = \left(\frac{120}{0.08}\right) m/sec = 1500 m/sec$$

$\boxed{v = 1500 m/sec}$ Answer

**Q3: A gunshot from a ·22 rim fire rifle has an intensity of about $I = (2.5 \times 10^{13}) I_o$. Do we need to wear ear protection? (Considering that prolonged exposure to sounds above 85 decibels can cause hearing damage or loss).**

Solution:

Given data: Intensity $= I = 2.5 \times 10^{13} I_o$

Intensity level limit $= 85 dB$

Required: (a) Intensity level $= I.L = ?$

(b) Ear protection $= ?$

Calculation: (a) We know that

$$\text{Intensity level} = I.L = 10 \log\left(\frac{I}{I_o}\right) \text{——— (1)}$$

Putting the values in equation (1), we get

$$I.L = 10 \log\left(\frac{2.5 \times 10^{13} I_o}{I_o}\right) = 10 \log(2.5 \times 10^{13})$$

$$\Rightarrow I.L = 10 \times 13.39$$

$\Rightarrow \quad I \cdot L = 133 \cdot 9\,dB$

$\boxed{I \cdot L = 134\,dB}$ Answer

(b) As we have given that safe intensity level limit is 85dB, so 134dB is too greater than 85dB· So we need to wear ear protection·

**Q4: What sound intensity level in dB is produced by earphones that create an intensity of 4·00 x $10^{-2}W/m^2$? (Use the usual reference level of $I_o$ = 1·00 x $10^{-12}W/m^2$)**

Solution:

Given data:

Intensity of sound $= I = 4 \cdot 0 \times 10^{-2} W/m^2$

Usual reference level of $I_o = 1 \cdot 0 \times 10^{-12} W/m^2$

Required: Intensity level $= I \cdot L = ?$

Calculation: We know that

$$I \cdot L = 10 \log\left(\frac{I}{I_o}\right) \text{ ——— } (1)$$

Putting the values in equation (1), we get,

$$I \cdot L = 10 \times \log\left(\frac{4 \times 10^{-2}}{1 \times 10^{-12}}\right) = 10 \times \log\left(4 \times 10^{10}\right)$$

$\Rightarrow \quad I \cdot L = 10 \times \log(40000000000)$

$\Rightarrow \quad I \cdot L = 10 \times 10 \cdot 60205999$

$\boxed{I \cdot L = 106 \cdot 02\,dB}$

$\boxed{\text{Intensity level} = I \cdot L = 106 \cdot 02\,dB}$ Answer

**Q5: What is the speed of sound in air at -20°C?**

Solution:

Given data: Temperature $= t = -20°C$

Required: Speed of sound $= v = ?$

Calculation: We know that,

$$v = 331 + 0.6T \text{ ——— } (1)$$

Put $T = -20°C$ in equation (1), we get,

$$v = [331 + 0.06 \times (-20)] m/sec$$

$$\Rightarrow v = (331 - 12) m/sec = 319 m/sec$$

Speed of sound at $-20°C = v = 319 m/sec$ Answer

**Q6: Army man wearing binoculars see the flash from enemy tank fire 5s before the fire is heard, he records 26°C temperature on his personal thermometer. What is the distance of the tank from him?**

Solution:

Given data: Time $= t = 5 sec$

Temperature $= T = 26°C$

Required: Distance of tank $= S = ?$

Calculation: We know that,

$$S = vt \text{ ——— } (1)$$

Also $v = 331 + 0.6T$ ——— (2)

Putting equation (2) in equation (1), we get,

$$S = (331 + 0.6T)t \text{ ——— } (3)$$

Putting the values of "T" and "t" in equation (3), we get,

$$S = [(331 + 0.6 \times 26) \times 5] m$$

$$\Rightarrow S = (346.6 \times 5) m = 1733 m$$

$$\Rightarrow S = 1.733 \times 10^3 m = 1.733 km \quad [10^3 = Kilo]$$

$$\Rightarrow S = 1.7 km$$

Distance of tank $= S = 1.7 km$ Answer

**Q7: Calculate the wavelengths of sounds at the extremes of the audible range, 20Hz and 20,000Hz, at normal room temperature of 20°C?**

**Solution:**

**Given data:** Frequency $= f_1 = 20Hz$

Frequency $= f_2 = 20000Hz$,

Temperature $= T = 20°C$

**Required:** (i) Wavelength at frequency "$f_1$" $= \lambda_1 = ?$

(ii) Wavelength at frequency "$f_2$" $= \lambda_2 = ?$

**Calculation:** (i) We know that, $v = f\lambda$

$$\Rightarrow \lambda = \frac{v}{f} \Rightarrow \lambda_1 = \frac{v}{f_1} \text{ ——— } (1)$$

Also $v = 331 + 0.6T$ ——— (2)

Putting equation (2) in equation (1), we get,

$$\lambda_1 = \left(\frac{331 + 0.6T}{f_1}\right) \text{ ——— } (3)$$

Putting the values of "T" and "$f_1$", we get,

$$\lambda_1 = \left(\frac{331 + 0.6 \times 20}{20}\right)m = \left(\frac{331 + 12}{20}\right)m$$

$$\Rightarrow \lambda_1 = \left(\frac{343}{20}\right)m \Rightarrow \lambda_1 = 17.15m$$

(OR) $\boxed{\lambda_1 = 17m}$

(ii) For "$\lambda_2$" we replace "$f_1$" by "$f_2$" in equation (3), so we get,

$$\lambda_2 = \left(\frac{331 + 0.6T}{f_2}\right) \text{ ——— } (4)$$

Putting the values of "T" and "$f_2$" in equation (4), we get,

$$\lambda_2 = \left(\frac{331+0\cdot6\times20}{20000}\right)m$$

$$\Rightarrow \lambda_2 = \left(\frac{343}{20000}\right)m = 0\cdot017m$$

$$\Rightarrow \boxed{\lambda_2 = 0\cdot017m}$$

(OR) $\lambda_2 = (0\cdot017\times100)cm$

$$\Rightarrow \boxed{\lambda_2 = 1\cdot7cm}$$

$\boxed{(i)\ \lambda_1 = 17m}$ $\boxed{(ii)\ \lambda_2 = 1\cdot7cm}$ Answer

**Q8: Ishfaq stands between two high rise buildings A and B, such that he is at 33m distance from building A. When he blows the whistle, he hears the first echo after 0·2s and second echo after 0·8s. Calculate (a) the speed of sound and (b) distance of building B from him.**

**Solution:**

**Given data:**

Distance of Ashfaq from building "A" = $S_1 = 33m$,

Total time for 1st echo $= T_1 = 0\cdot2sec$,

Total time for 2nd 2cho $= T_2 = 0\cdot8sec$,

**Required:**

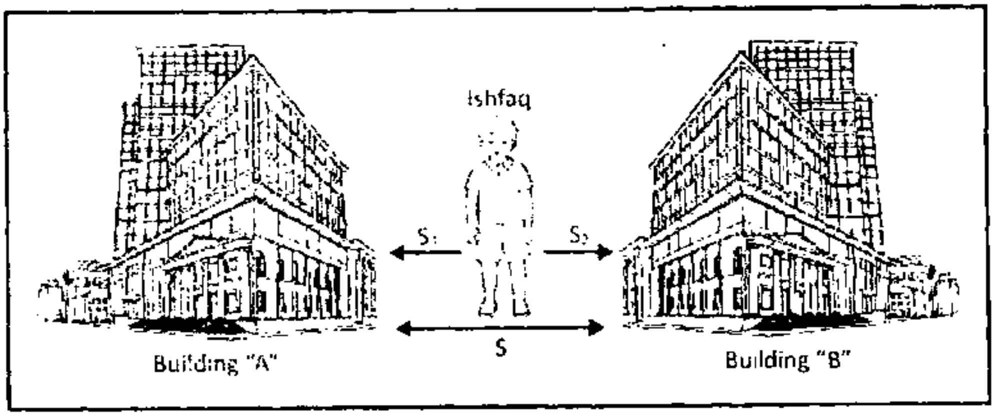
(i) Speed of sound $= v = ?$

(ii) Distance of building "B" from Ashfaq $= S_2 = ?$

**Calculation:**

(i) The time taken by sound waves to reach building "A" $= t_1 = \frac{T_1}{2} = \frac{0\cdot2}{2} = 0\cdot1sec$

$$\Rightarrow t_1 = 0\cdot1sec$$




Now the speed of sound waves is given by,

$$S_1 = vt_1 \Rightarrow v = \frac{S_1}{t_1} = \frac{33}{(0.1)} = 330m/sec$$

$$\Rightarrow \boxed{v = 330m/sec}$$

(ii) Now the time taken by sound waves to reach building "B" is given by,

$$t_2 = \frac{T_2}{2} = \frac{0.8}{2} = 0.4sec$$

$$\Rightarrow t_2 = 0.4sec$$

Now the distance of building "B" from the Ashfaq is given by,

$$S_2 = vt_2 \quad \Rightarrow S_2 = (330 \times 0.4)m$$

$$\Rightarrow \boxed{S_2 = 132m}$$

Answers:

(i) Speed of sound = $v = 330m/sec$

(ii) Distance of building "B" from Ashfaq = $S_2 = 132m$

OOO

۞ علم کی خوبی اس پر عمل کرنے میں اور احسان کی خوبی اس کے نہ جتلانے پر منحصر ہے۔

۞ خندہ روئی سے پیش آنا سب سے پہلی نیکی ہے۔

CHAPTER 12

# GEOMETRICAL OPTICS

***Q1: Define reflection of light. State and explain the laws of reflection of light.***

روشنی کے انعکاس سے کیا مراد ہے؟ روشنی کے قوانین انعکاس کی وضاحت کریں۔

*Ans. Definition [تعریف]*

*"The bouncing back of light rays from the surface of a certain medium is known as reflection of light."*

*Laws of Reflection of Light [روشنی کے انعکاس کے قوانین]*

*The laws of reflection of light were first discovered by a Muslim scientist "Ibnal Haitham". There are two laws of reflection of light, which are given below:*

*1) First Law of Reflection [پہلا قانونِ انعکاس]*

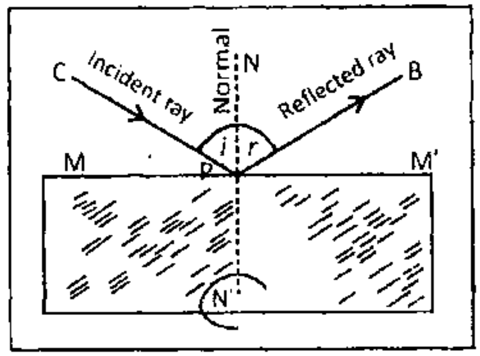
*This law states that, "the angle of incidence [زاویۂ وقوع] "$\angle i$" is equal to the angle of reflection [زاویۂ انعکاس] "$\angle r$" i.e.*

$$\angle i = \angle r$$

*2) Second Law of Reflection [دوسرا قانونِ انعکاس]*

*This law states that, "the incidence ray, the reflected ray and normal [عمود] to the interface at the point of incidence [نقطۂ وقوع] all lie in the same plane."*

*Explanation (وضاحت):*




Consider a plane surface " MM' ", as shown in the figure. Let a ray of light coming the point "C" is allowed to fall on point "P" of the surface. This ray "CP", is known as incidence ray. The angle made by the incident ray with normal "NN' ", is known as angle of incidence "$\angle i$". During this process, some light rays reflect from the surface at point "P", which is known as reflected ray "BP". The angle made by the reflected ray "BP" with normal is known as angle of reflection "$\angle r$ ".

Now from the above figure, it is clear that,

1. The angle of incidence is equal to the angel of reflection and
2. The incidence ray, the reflected ray and the normal, all lie in the same plane. Thus the laws of reflection of light are verified.

**Q2: Define (a) Mirror and spherical shell? (b) What are spherical mirrors? Discuss their types.**
آئینہ اور کروی خول سے کیا مراد ہے؟ کروی آئینے کیا ہوتے ہیں؟ اس کی اقسام بیان کریں۔

Ans. (a) Mirror:
(BISE Peshawar, Swat, Malakand, Kohat 2019)
The smooth and polished surface of a medium which reflects most of the light rays is known as mirror.

Spherical Shell [کروی خول]

A hollow [خالی] spherical object, is known as spherical shell.

### (b) Spherical Mirrors [کروی آئینے]

A section of spherical shell whose inner or outer surface is able to reflect light is known as spherical mirror.

#### Types of Spherical Mirrors [کروی آئینوں کی اقسام]

There are two types of spherical mirrors, which are given below:

**1) Convex Mirror [محدب آئینے]**

The mirror whose shining surface bulges outwards is known as convex mirror. This mirror is able to diverge the parallel rays of light after falling upon it. So it is also known as diverging mirror.

**2) Concave Mirror [مقعر آئینہ]**

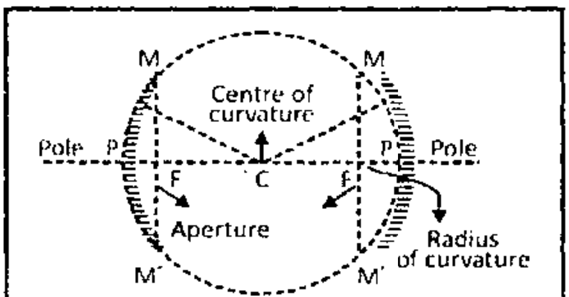
The mirror whose shining surface curves inwards is known as concave mirror. This mirror is able to converge the parallel rays of light after falling upon it. So it is also known as converging mirror.

**Q3: Define the following terms: centre of curvature, radius of curvature, pole, aperture, principal axis, principal focus and focal length.**

مندرجہ ذیل اصطلاحات کی تعریف کریں: مرکز انحناء، انحناء کا نصف قطر، قطب، سہوہ، محور خاص، ماسکہ خاص، طول ماسکہ

**Ans. (1) Centre of Curvature [مرکز انحناء]**

The centre of the hollow sphere of which the mirror is a part, is known as centre of curvature, as shown by point "C" in given figure.



Convex Mirror & Concave Mirror

(2) Radius of Curvature [انحناء کا رداس]

The radius of the sphere of which the mirror is a part is known as radius of curvature, as shown by ling "CP" in the given figure.

(3) Pole [قطب]

The geometric central point of the mirror is known as pole, as shown by point "P" in the given figure.

(4) Aperture [گھیرا]

The diameter of the mirror is known as aperture, as shown by line "MM' " in the given figure.

(5) Principal axis [محور خاص]

The line which passes through the pole "P" and centre of curvature "C", is known as principal axis of the mirror.

(6) Principal Focus of Concave Mirror [مقعر آئینے کا ماسکہ خاص]

The point where the parallel rays of light converge after reflection from concave mirror, is known as principal focus. This point is represented by point "F" in given figure.

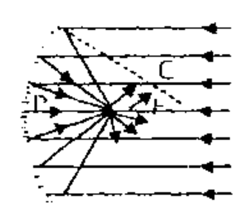


Fig. (I)

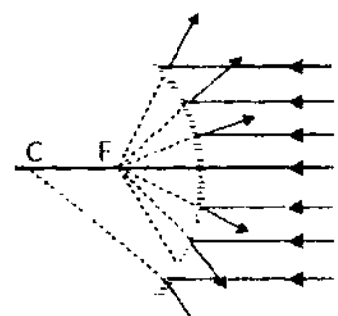


Fig. (II)
Focal length of a convex mirror

(7) Focal Length of Concave Mirror [مقعر آئینے کا طول ماسکہ]

The distance between the pole and principal focus is known as focal length of cave mirror as shown by line "PF" in figure (i). The focal length of concave mirror is taken as positive and is equal to half of the radius

of curvature i.e. $f = \frac{R}{2}$.

8) Principal Focus of Convex [محدب آئینے کا ماسکہ خاص]

When parallel rays of light falls upon a convex lens, they diverges from the mirror in such a way, that they appears to come from a point which is known as principal focus of convex mirror.

9) Focal Length of Convex Mirror [محدب آئینے کا طول ماسکہ]

The distance between pole and principal focus of convex mirror is known as focal length of convex mirror. It is taken as positive.

**Q4: Define spherical mirror. How does it reflect light? Discuss the uses of mirrors.**
کُروی آئینے کیا ہوتے ہیں؟ ان میں روشنی کا انعکاس کیسے ہوتا ہے؟ اس کے استعمال یا فوائد بیان کریں۔

Ans. Spherical Mirrors [کُروی آئینے]: (BISE Bannu 2019)

A section of spherical shell whose inner or outer surface is able to reflect light is known as spherical mirrors.

Reflection of Light from Spherical Mirrors
[کُروی آئینوں سے روشنی کا انعکاس]

As the inner or outer surface of the mirror is smooth and polished, so these mirrors has the ability to reflect light rays. Some special type reflections of light from the mirror are given below:

Case 1: If the incident rays of light are parallel to the principal axis, then such ray of light will passes through the focus after reflection from the mirror, as shown in figure (a).

Case 2: If the incident ray passes through the focus, then such ray will becomes parallel to principal

*axis after reflection from mirror, as shown in figure (b)·*

*Case 3: If the incident ray passes through the centre of curvature, then such ray of light will reflect back along the same path, as shown in figure (c)·*

*Case 4: If the incident ray falls on the pole by making an angle "θ" with principal axis, then such ray of light will make same angle "θ" with principal axis after reflection, as shown in figure (d)·*

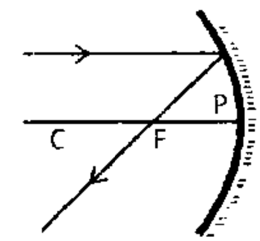



Fig. (a)

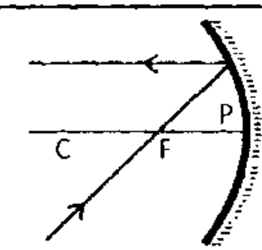



Fig. (b)

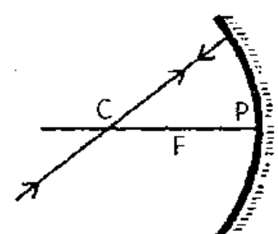



Fig. (c)

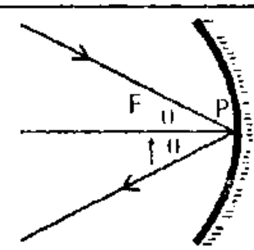



Fig. (d)

*Uses of Mirrors [آئینوں کا استعمال]*

1. *The convex mirrors are used in vehicles [گاڑی] to see other objects clearly behind the vehicles·*
2. *The convex mirrors are used at dangerous roads bends for safe drive·*
3. *The concave mirrors are used by doctors to examine ears, nose, throat and eyes·*
4. *The concave mirrors are used in car head lights, spot light in tion rooms in a hospital·*
5. *The concave mirrors are also used for throwing light on the slides of microscope for clear*

observations.

6. The concave mirrors are also used for collecting signals of microwaves from satellite to a focus.

**Q5: An object is brought from long distance towards a concave mirror. Discuss the features of the image as an object is brought closer and closer. Support your answer by drawing figures.**

کسی جسم کو ایک مقعر آئینہ کے قریب لامتناہی فاصلہ سے لایا جاتا ہے۔ اس کی شبیہہ میں رونما ہونے والی تبدیلیوں کا تفصیل سے جائزہ لیں۔ اشکال سے وضاحت کریں۔

Ans. We can get information about the size, position and nature of the image of an object by placing the object at different positions from the concave mirror.

Case 1: When object is placed beyond the centre of curvature [جب جسم مرکز انحناء سے پرے واقع ہو]

Consider a distant object "AB" placed beyond the centre of curvature "C", as shown in figure (a). Let two rays (1) and (2) coming from point "A" in such a way, that ray (1) is parallel to principal axis and ray (2) passes through the centre of curvature, as shown in figure (a).

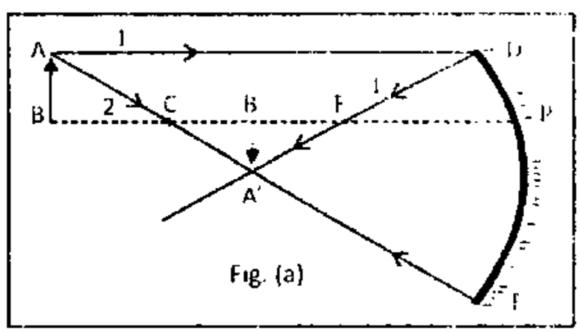


Fig. (a)

These two rays reflect from the concave mirror and meet each other. Thus an image [شبیہہ] "A'B'" is

formed which is real [حقیقی], inverted [اُلٹی] and smaller in size than the object. This image can be obtained on the screen.

*Case 2: When object is placed at the centre of curvature "C" [جب جسم مرکز انحنا پر واقع ہو]*

In this case the object "AB" is placed at the centre of curvature "C" of concave mirror. Let two rays (1) and (2) coming from point "A"

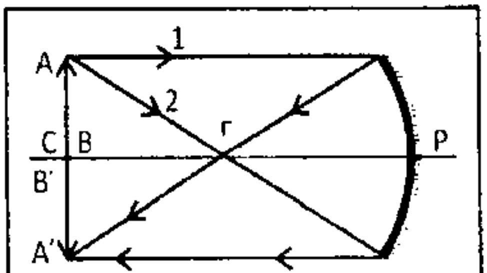


Fig. (b)

in such a way, that ray (1) is parallel to principal axis and ray (2) passes through the principal focus, as shown in figure (b). These two rays of light reflect from the mirror and meet each other. Thus an image "A'B'" is formed, which is real, inverted and its size is equal to the size of the object.

*Case 3: When object is placed between the centre of curvature and principal focus "F" [جب جسم مرکز انحنا اور ماسکہ کے درمیان ہو]*

In this case the object "AB" is placed in front of the centre of curvature of the mirror, as shown in figure (c). Let two rays (1) and (2) coming from point "A" in such a way,

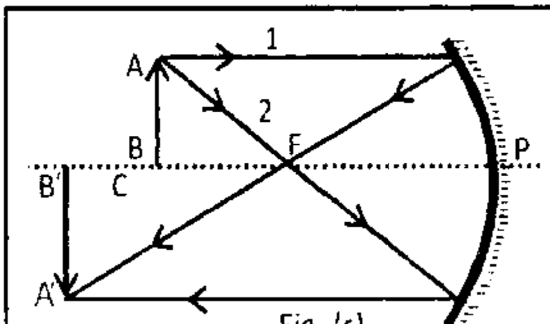


Fig. (c)

*that ray (1) is parallel to principal axis and ray (2) passes through principal focus, as shown in figure (c).*

*These rays reflect from the mirror and intersects [قطع کرنا] each other. Thus an image "A'B'" is formed beyond the object, which is real, inverted and greater in size than object.*

***Case 4: When object is placed at the principal focus "F" [جب جسم ماسکہ خاص پر واقع ہو]***

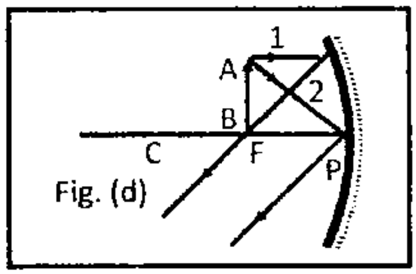


Fig. (d)

*In this case, the object is placed at the principal focus of the concave mirror, as shown in figure (d). The two rays coming from point "A" reflects from the mirror and the image is formed at infinity [لا متناہی فاصلہ]. This image will be very large, inverted and real.*

***Case 5: When object is placed between principal focus and pole of the mirror [جب جسم ماسکہ خاص اور قطب کے درمیان واقع ہو]***

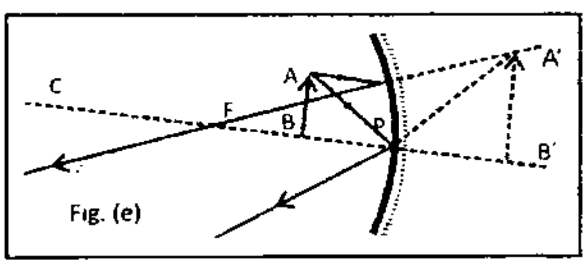
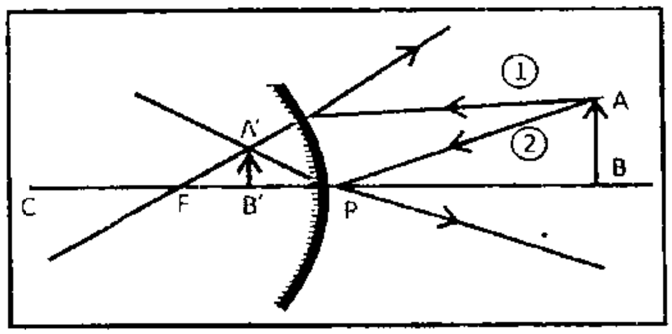


Fig. (e)

*In this case the object is placed between principal focus and pole of concave mirror. The two rays coming from point "A" reflects from the mirror and diverges as shown in figure (e). So these rays will not meet each other, but if we proceed these rays behind the mirror, then they will meet each other virtually. Thus a virtual, enlarge and erect image "A'B'" will appear behind the mirror.*

**Q6: Discuss the formation of image formed by a convex mirror.** محدب آئینے کے ذریعے بننے والے شبیہ پر بحث کریں۔

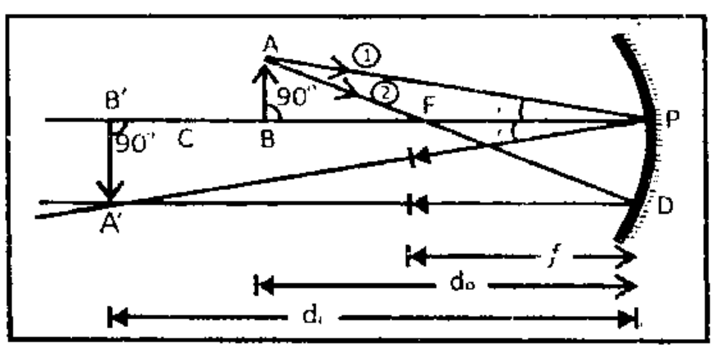
Ans. Consider an object "AB" is placed in front of a convex mirror as shown in the figure. Let two rays (1) and (2) coming from point "A" are allowed to fall on the convex mirror.




These two rays reflect from the mirror in such a way that their angle of incidence is equal to their angles of reflection. Now if we proceed these rays towards left of the mirror, then these rays will meet each other virtually and thus produce smaller, upright and virtual image "A'B'" as shown in the above figure.

**Q7: Derive the spherical mirror equation (formula) for a concave mirror.** مقعر آئینے کے لیے کلیہ اخذ کریں۔

Ans. The spherical mirror formula gives us the relation between distance of object, distance of image and focal length of the spherical mirror.



As $A'B' = q$ and $AB = p$, so equation (i) ⇒

$$\boxed{M = \frac{q}{p}} \quad \text{——— (2)}$$

OR $$\boxed{M = \frac{d_i}{d_o}} \quad \text{——— (3)} \qquad [q = d_i, p = d_o]$$

Equation (1), (2) and (3) represents the linear magnification. It has no unit, because it the ratio between two similar quantities.

**Q9: Distinguish between real image and virtual image. Give sign convention for the images formed by spherical mirror.**

حقیقی شبیہ اور مجازی شبیہ میں کیا فرق ہے؟ کروی آئینوں سے بننے والے شبیہوں کے مروج علامتیں بیان کریں۔

Ans.

1. The real image can be obtained [حاصل کرنا] on the screen, where as the virtual image cannot be obtained on the screen.
2. In case of real image, the rays of light actually meet each other, while in case of virtual image, the rays of light virtually meet each other.
3. The real image is always inverted [الٹا] while the virtual image is always erect.
4. The distance of real image is taken as positive, while the distance of virtual image is taken as negative.

**Q10: Distinguish between regular and irregular reflection of light. Discuss their importance.**

روشنی کے باقاعدہ اور بے قاعدہ انعکاس میں فرق واضح کریں اور اس کی اہمیت بیان کریں۔

Ans. 1) <u>Regular Reflection [باقاعدہ انعکاس]</u>

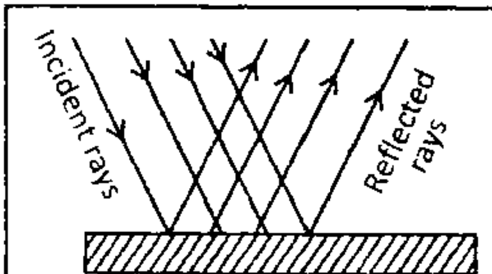
"The reflection in which the angle of incidence is equal to the angle of reflection is known as regular reflection of light."

**Explanation [وضاحت]**

When parallel rays of light are allowed to fall on a smooth and polished surface then the rays reflect from the surface properly in a particular direction. Such reflection of light is called regular reflection of light.

**Importance of Regular Reflection**

With the help of regular reflection of light, we can converge or diverge rays of light according to our needs and desires. Such reflection can be used for the formation of images by using mirrors.



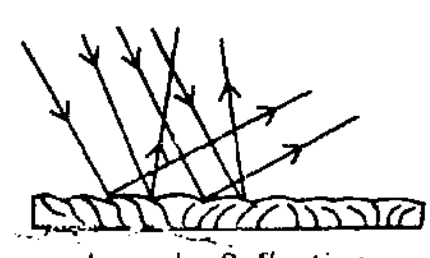
Regular Reflection of Light

**2) Irregular Reflection [بے قاعدہ انعکاس]**

"The reflection in which the angle of incidence is not equal to the angle of reflection is called irregular reflection of light."

**Explanation [وضاحت]**

When parallel rays of light are allowed to fall on an irregular surface, then the rays reflects from the surface irregularly, as shown in the figure. Such reflection of light is known as irregular reflection of light.


Irregular Refleetion

*Importance of Irregular Reflection*

1. With the help of irregular reflection, we can see non luminous objects.
2. The sun light scatters in different direction due to irregular reflection of light.
3. The irregular reflection enables the light to reach everywhere.

**Q11: Define refraction of light. State and explain laws of refraction of light.**
روشنی کے انعطاف سے کیا مراد ہے؟روشنی کے قوانین انعطاف بیان کریں۔

Ans. "This slightly bending of light from its original path is known as refraction of light."

*Laws of Refraction of Light [روشنی کے قوانین انعطاف]:*

(BISE Kohat, Mardan, Swat 2019)

There are two laws of refraction of light which are given below:

1) *First Law of Refraction of Light*

"This law states that the incident ray, refracted ray and normal at point of incidence all are lie in the same plane."

2) *Second Law of Refraction of Light*

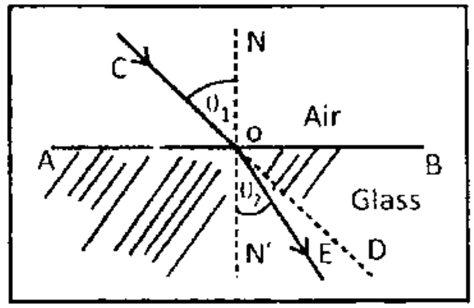
"The law states that the ratio between the sine of the angle of incidence "$\theta_1$" to the sine of angle of refraction "$\theta_2$" is constant for a given pair of media."

i.e. $$\frac{\sin\theta_1}{\sin\theta_2} = n \longrightarrow (i)$$

In equation (i), "n" is constant and is known as refractive index of the two medium. This law is al-

so known as Snell's law.

Explanation [وضاحت]




Let "AB" be the surface of separation between the two mediums i.e. [air and glass] as shown in the figure. Let a ray of light "CO" is incident on the surface "AB" at point "O". This ray enters from air into the glass and bends slightly from its original path "OD". This refracted ray is shown in the figure by line "OE".

Now the angle "$\theta_1$" with normal "NON'" is known as angle of incidence, while the angle "$\theta_2$" is known as angle of refraction.

Conclusion [نتیجہ]

The above discussion shows that, the incident ray, the reflected ray and normal all are lie in the same plane. We also see that the angle "$\theta_1$" and "$\theta_2$" depends upon each other. Thus the laws of refraction of light are verified.

**Q12: Define refractive index. How it is related to Snell's law as well as velocity of light in a pair of transparent media? How would you determine the refraction index of water by finding the real and apparent depth of water in a container?**

Ans. "The ratio between sine of angle of incidence "$\theta_1$" and sine of angle of refraction "$\theta_2$" is known as refractive index".

## Explanation [وضاحت]

According to Snell's law we have,

$$\frac{\sin\theta_1}{\sin\theta_2} = n \quad \text{——— (1)}$$

In equation (1), "n" is constant and represents the refractive index for a pair of transparent media. With the help of refractive index, we can compare the velocity of light in two different media. We know that the speed of light through vacuum [خلاء] or air is $3\times10^8\ m/sec$.

Now the refractive index of a medium relative to vacuum (or air) is given by,

n = Speed of light in air/speed of light in medium

$$\Rightarrow \quad n = \frac{c}{v} \quad \text{——— (2)}$$

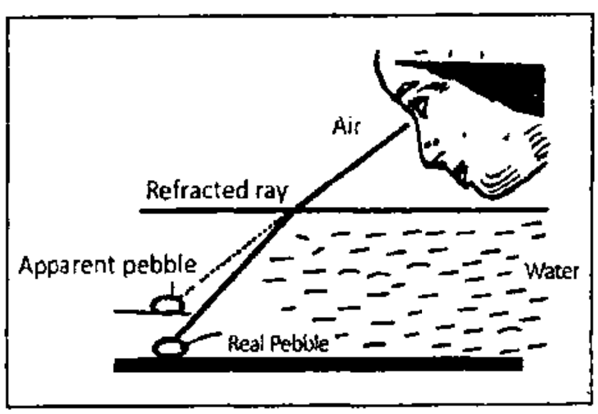
Comparing equation (1) and (2), we get,

$$n = \frac{\sin\theta_1}{\sin\theta_2} = \frac{c}{v} \quad \text{——— (3)}$$

Equation (3) shows that the refractive index will be greater if the speed of light "v" in the given medium is slower and vice versa.

## Refractive Index of Water

We know that when light rays enters in air from water, they refracts away from the normal. In the given figure, a pebble [کنکر] in wa-



ter is shown. But due to refraction of light, the pebble seems to us at raised position. This depth of the pebble at the apparent position [ظاہری مقام] is known as apparent depth. While the actual position of the pebble in water is known as its real depth. With the help of apparent depth and real depth, we can find out the refractive index of water. i.e.

$$n = \frac{\text{real depth}}{\text{apparent depth}}$$

| Indices of Refraction for Some Common Materials | |
|---|---|
| Material | Index of Refraction |
| Gases | |
| Air | 1.000271 |
| Helium | 1.000036 |
| Carbon dioxide | 1.00045 |
| Liquids | |
| Water | 1.333 |
| Methyl alcohol | 1.329 |
| Ethyl alcohol | 1.362 |
| Glycerine | 1.473 |
| Benzene | 1.501 |
| Typical oil | 1.5 |
| Solids | |
| Ice | 1.310 |
| Calcium fluoride | 1.434 |
| Fused quartz | 1.46 |
| Salt | 1.544 |
| Polystyrene | 1.49 |
| Typical glass | 1.5 |

| | |
|---|---|
| Crown glass | 1·52 |
| Quartz | 1·544 |
| Diamond | 2·417 |

**Q13: What is prism? Discuss the refraction and deviation of light by a prism.**

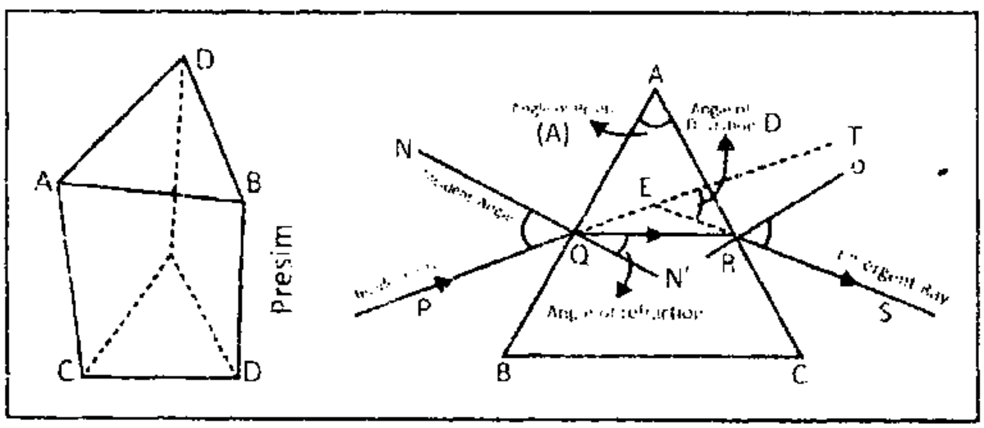
منشور کیا ہوتا ہے؟ منشور سے روشنی کے انعطاف اور انحراف پر بحث کریں۔

Ans. Prism

A prism is a transparent refracting body which is bounded by three rectangular and two triangular surfaces.

Refraction and Deviation of Light by a Prism

Consider a ray "PQ" is incident on a prism, when this ray enters the prism, it bends towards the normal "N'N " from its original path "QT". This refracted ray is shown by the line "QR" in the given figure.




This ray strikes the other face of the prism at point "R" and emergent out. As the outside medium is air [which is rare medium] so the emergent ray "RS" bends away from the normal "OR". If we proceeds the emergent ray "RS" in the backwards

direction, it will meet the original path of the incident ray at point "E". Thus the angle "$T\hat{E}S$" gives us the angle of deviation which is represented by "D", while the angle opposite to the base of the prism is known as angle of prism. It is represented by "A". Now the refractive index of the prism can be obtained from the following relation. i.e.,

$$n = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\left(\frac{A}{2}\right)} \qquad \text{--- (1)}$$

In equation (1) "A" represents the angle of prism and "$D_m$" represents the angle of minimum deviation [زاویہ انحراف اقل].

**Q14: Explain total internal reflection of light. What are the conditions for total internal reflection of light?**

روشنی کے کلی داخلی انعکاس کی وضاحت کریں اور اس کے لیے شرائط بیان کریں۔

Ans. Definition

"The reflection of light totally from the boundary of interface is known as total internal reflection of light."

Explanation [وضاحت]

We know that when light passes from a denser me-

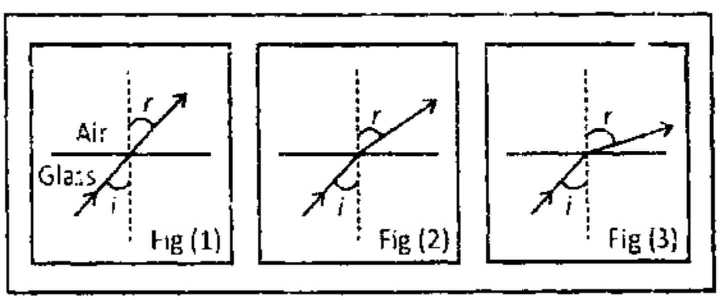
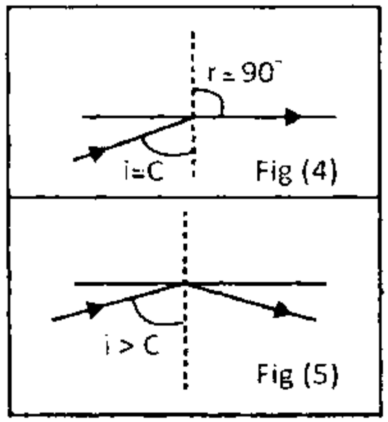


Fig (1) Fig (2) Fig (3)

dium to a rare medium, then the incident ray refracts [منعطف] from its original path. Now if we increase the angle of incidence with normal gradually, then the angle of refraction also increases, as shown in the figures.

Finally a stage come, when for certain value of angle of incidence, the refracted ray makes an angle of 90° with normal, as shown in figure (4). Such angle of incidence for which the angle of refraction becomes 90°, is known as critical angle. This angle is represented by "C".




Now on further increasing the angle of incidence, the incident ray totally reflects from the boundary of interface, as shown in figure (5). Such reflection of light is known as "total internal reflection".

Conditions for Total Internal Reflection

For total internal reflection, the following conditions must be satisfied.

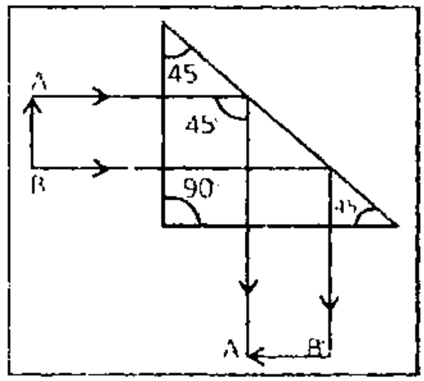
1. The incident ray should be pass from denser medium to a rare medium.
2. The angle of incidence should be greater than the critical angle. i.e. $i > c$

**Q15: Give some practical examples of total internal reflection of light.** کلی داخلی انعکاس کی عملی مثالیں بیان کریں۔

Ans. The practical examples of total internal reflection of light are given below:

1) Totally Reflecting Prism [کلی انعکاسی منشور]

Consider a ray of light is allowed to fall normally on one side of a right triangular glass prism as shown in the figure. This ray passes undeflected and strikes the base of the triangle by making an angle of 45° with the normal. This incident ray reflects totally from the base of the prism at an angle of 45° with the normal. This reflected ray then passes the other side of the prism normally and passes out without any further deviation. This property of total internal reflection is used in periscope as reflectors.

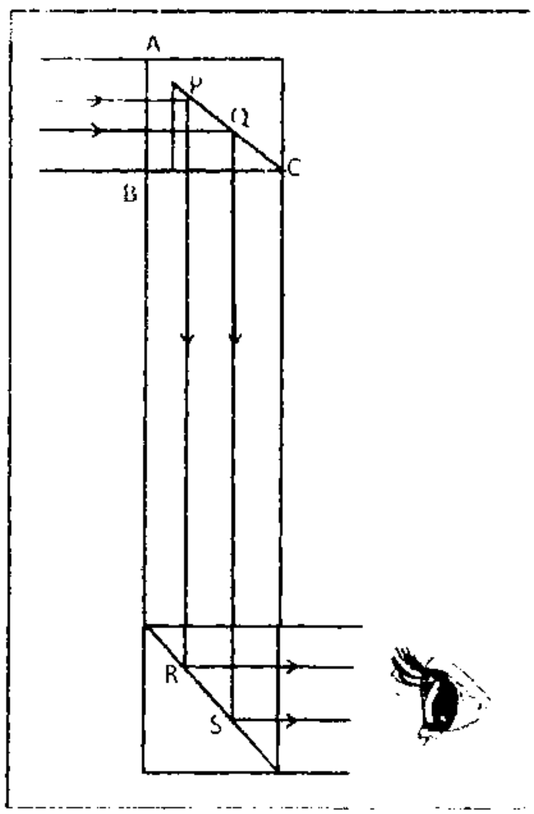



2) Periscope [پیری سکوپ]

The periscope is an optical instrument with the help of which we can see those things which are not directly in sight.

Construction [ساخت]

It consists of a tube and two reflecting glass prisms. These prisms are fitted at the end of the tube. The rays of light falls on the 1st glass prism



normally, passes undeflected and strikes the base at an angle of 45°. This incident ray totally reflects from the prism undeflected and becomes parallel, as shown in the figure.

With the help of periscope, we can see objects which are situated outside the walls of the house, by sitting the periscope in the lawn of houses. The periscope can be also use in tanks, submarines etc for observing various objects from a safer position.

### 3) The Binoculars

The binoculars also make use of prism to reduce the length of the instrument and to produce an erect image.

### 4) Optical Fibres [آپٹیکل فائبر]

The optical fibres are thin glass rods which can trap light by total internal reflection.

#### Principle of Working

It works on the principle of total internal reflection of light.

#### Construction

It consists of flexible glass rod, which is coated with another glass whose refractive index is less than the 1st glass rod. The ray of light enters the fibres at one end. This ray totally reflects from the sides and finally come out at the other end.

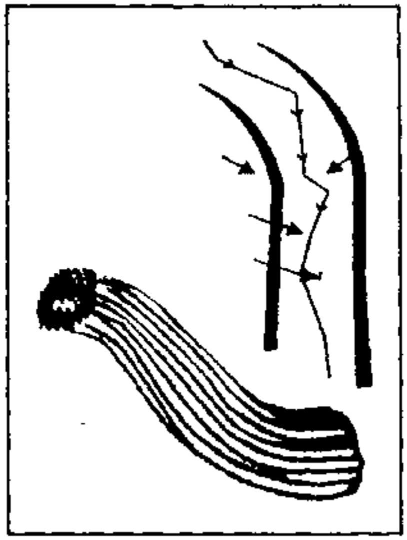
#### Uses of Optical Fibres

1. It is used by the doctors to see different parts of human body on the screen.
2. The optical fibres are used in telephones and other communication systems.

### 5) Endoscope [اینڈوسکوپ]

It is another important optical instrument which works on the principle of total internal reflection of light.

The endoscope is used for viewing and photographing the inside of a hollow organ of the body such as bladder, stomach etc. For this purpose, optical fibres are used in endoscope, which makes the interior parts of the body more visible and thus the doctor can check the problems of the patient very easily. "Gastroscope" is the example of endoscope which is used by doctors to examine the stomach.



**Q16: Define the critical angle for total internal reflection. What is the relationship between the critical angle and the angle of refraction?**

کلی داخلی انعکاس کیلئے زاویہ فاصل کی تعریف کریں۔ زاویہ فاصل اور زاویہ انعطاف میں کیا تعلق ہے؟

Ans. "The angle of incidence for which the angle of refraction becomes 90° is known as critical angle."

From Snell's law, we have,

$$\frac{\sin\theta_1}{\sin\theta_2} = n \quad \text{——— (1)}$$

Here we can obtain an expression for critical angle by putting the angle of incidence "$\theta = \theta_c$" and angle of refraction "$\theta_1 = 90°$". So equation (1) ⇒

$$\frac{\sin 90^\circ}{\sin\theta_c} = n \quad \Rightarrow \quad \frac{1}{\sin\theta_c} = n \Rightarrow \sin\theta_c = \frac{1}{n}$$

$$\Rightarrow \quad \theta_c = \frac{1}{\sin}\left(\frac{1}{n}\right) \Rightarrow \boxed{\theta_c = \sin^{-1}\left(\frac{1}{n}\right)} \text{———} (2)$$

*Now if the value of "n" is known, then using equation (ii), we can calculate the value of critical angle.*

**Q17: What is a lens? Discuss their types.**
عدسہ سے کیا مراد ہے؟ اس کے اقسام بیان کریں۔

*Ans. Lens [عدسہ]: (BISE Peshawar, Malakand 2019)*

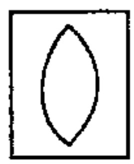
*A lens is a transparent material, bounded by two surfaces at least one of which must be curved.*

*Types of Lens*

*There two main types of lens which are given below:*

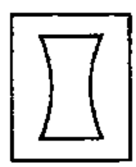
*1) Convex Lens*

*It is that lens which is thinner at the edges and thicker at the middle. It is also called converging lens, because it converges the parallel rays of light to a single point after passing through it.*



*2) Concave Lens*

*It is that lens which is thinner at the middle and thicker at the edges. The main property this lens is that, it diverge the parallel rays of light after passing through it.*



*Sub-Types of Convex Lens*

*There are three types of convex lens, which are given below:*

*1) Double-Convex Lens*

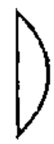
*It is that lens whose both sides are convex, as*

shown in figure (i).


(Fig. i)

2) Plano-Convex Lens

It is that lens whose one side is plane and the other side is convex, as shown in figure (ii).


(Fig. ii)

3) Concave-Convex Lens

It is that lens whose one side is concave and the other is convex, as shown in figure (iii).


(Fig. iii)

Sub-Types of Concave Lens

There are three types of concave lens, which are given below:

1) Double-Concave Lens

It is that lens whose both sides are concave, as shown in figure (iv).


(Fig. iv)

2) Plano-Concave Lens

It is that lens whose one side is plane and other is concave, as shown in figure (v).


(Fig. v)

3) Convex-Concave Lens

It is that lens whose one side is convex and other is concave, as shown in figure (vi).


(Fig. vi)

**Q18: Define the following terms: Principal focus, optical centre, principal axis, focal length, aperture, centre of curvature, radius of curvature**

مندرجہ ذیل اصطلاحات کی تعریف کریں: صدر ماسکہ، مناظری مرکز، صدر محور، طول ماسکہ، سموہ، مرکز انحناء، انحناء کا نصف قطر

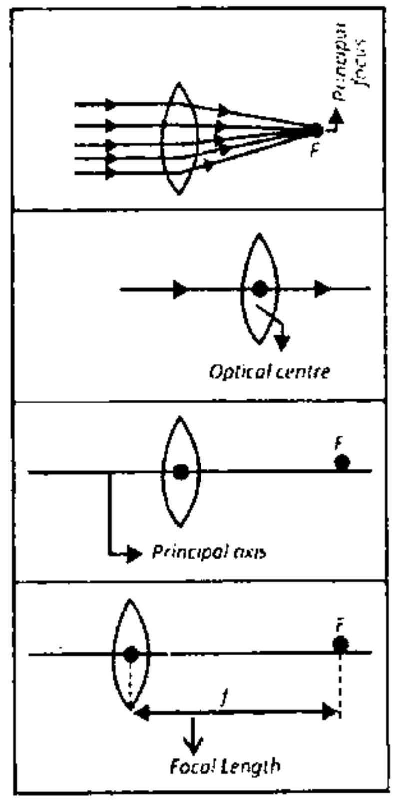
Ans. (1) Principal Focus [صدر ماسکہ]

It is the point where parallel rays of light meet

after passing through the lens·

(2) Optical Centre [بصری مرکز]

It is the point through which ray of light passes undeviated·




(3) Principal axis [صدر محور]

It is the line which passes through the optical centre and principal focus·

(4) Focal Length [طول ماسکہ]

The distance between optical centre and principal focus is known as focal length·

(5) Aperture [کرہ]

The diameter of the lens is known as aperture·

(6) Centre of Curvature [مرکز انحناء]

The centre of spherical surface of a lens is known as centre of curvatures·

(7) Radius of Curvature [انحناء کا نصف قطر]

The radius of spherical surface of a lens is known as centre of curvature·

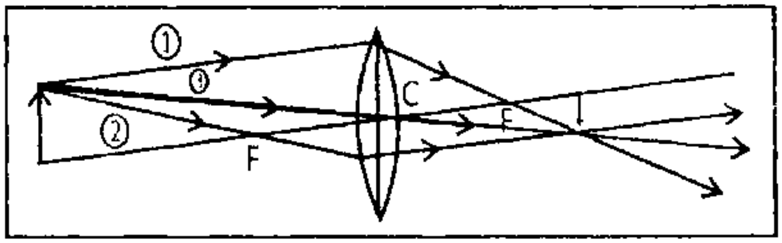
| |
|---|
| Q18: Discuss the refraction of special rays from a convex lens· کسی محدب عدسہ سے مخصوص شعاعوں کی انعطاف پر بحث کریں۔ |

Ans· The refraction of special rays are shown in the following figure·

Case 1: If the ray of light is parallel to the principle axis, then this ray will pass through the principal focus after refraction from the lens· This is

shown by ray (1) is given figure.

Case 2: If the ray of light passes through the principal focus "F", then this ray will become parallel to principal axis after refraction from the lens. This is shown by ray (2) in the given figure.




Case 3: If the ray of light passes through the optical centre, then this ray will pass undeflected. This is shown by ray (3) in the given figure.

**Q20: Discuss the formation of image formed by convex lens.** محدب عدسے کے ذریعے بننے والے شبیہوں کی وضاحت کریں۔

Ans. The size, nature [نوعیت] and position of the image formed by a convex lens depends upon the distance of object from the lens. Some cases are given below:

**Case 1: When object is placed beyond centre of curvature "C" or "2F"**

[جب جسم مرکز انحناء سے دور یا "2F" سے زیادہ فاصلے پر ہو]

Consider an object "AB" is placed beyond "2F" as shown in figure (a). Let two rays (1) and (2) coming from point "A" in such a way that ray (1) is parallel to principal axis and ray (2) passes through the optical centre, as shown in figure (a).

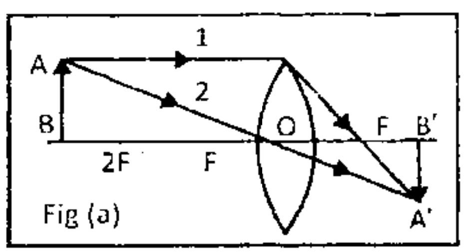



Fig (a)

The ray (1) passes through the principal focus after refraction from the lens. While ray (2) passes through optical centre undeflected. These two rays intersect each other and forms an image "A'B'" which is real, inverted and diminished.

**Case 2: When object is placed at centre of curvature "C" or at "2F"**

(جب جسم مرکز انحناء یا 2F فاصلے پر ہو)

In this case the object is placed at "2F" as shown in figure (b). The rays (1) and (2) coming from point "A" meet each other after passing through the lens, and form an image "A'B'" at "2F". This image is real, inverted and of the same size as object.

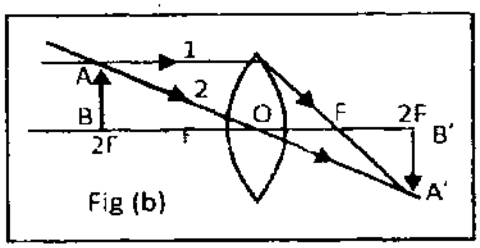


Fig (b)

**Case 3: When object is placed between "F" and "2F"**

[جب جسم "F" اور "2F" کے درمیان واقع ہو]

In this case the object is placed between "F" and "2F" as shown in figure (c). The rays (1) and (2) coming from point "A" meet each other after passing through the lens, and form an image "A'B'" beyond "2F". This image is real, inverted and magnified.

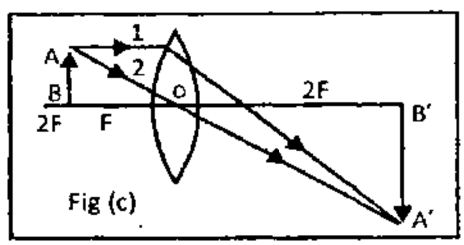


Fig (c)

**Case 4: When object is placed at principal focus "F"**

[جب جسم صدر ماسکہ "F" پر واقع ہو]

In this case, the object is placed at principal focus "F"

as shown in figure (d). The rays (1) and (2) coming from point "A" becomes parallel after passing through the lens.

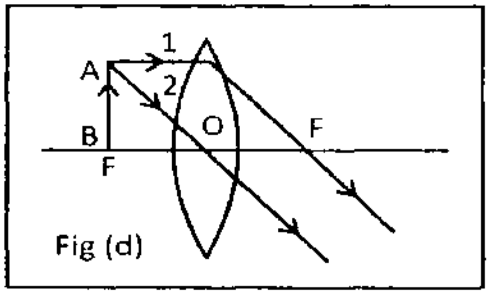


Fig (d)

***Case 5: When object is placed between principal focus "F" and the lens***

[جب جسم صدر ماسکہ "F" اور عدسے کے درمیان واقع ہو]

In this case, the object is placed between "F" and the lens, as shown in figure (e). The rays (1) and (2) coming from point "A" diverges from each other after passing through the lens. But if we proceeds these rays beyond the object, then they appears to form an image "A'B'" which is virtual, erect and magnified.

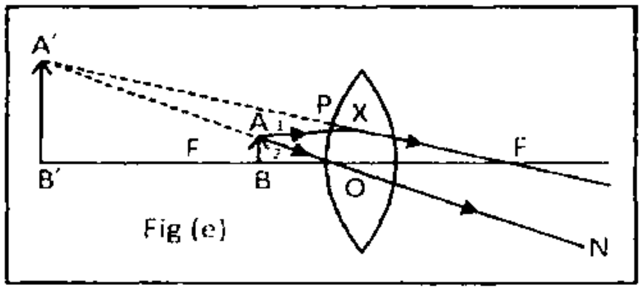
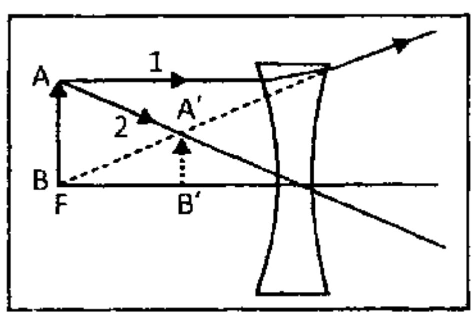


Fig (e)

**Q21: Discuss the formation of image by a concave lens.**
**کسی مقعر عدسہ سے شبیہ کی بناوٹ پر بحث کریں۔**

Ans. Consider two rays (1) and (2) coming from an object "AB" as shown in the figure. These rays diverge from each other, but if we proceeds these rays towards object, they appears to intersect each other and form an image "A'B'" which is virtual,



erect and diminished, as shown in the figure.

**Q22: Define and explain power of the lens.**
**(BISE Swat 2019)** عدسے کی طاقت سے کیا مراد ہے؟وضاحت کریں۔

Ans. Definition

The reciprocal of focal length of the lens is known as power of the lens.

Explanation [وضاحت]

The power of the lens is represented by "D" and is given by; $D = \frac{1}{f}$

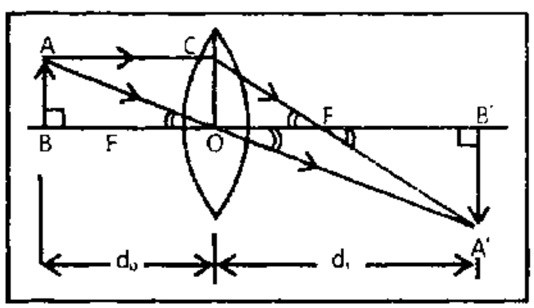
It is expressed in meter. The power of lens for convex lens is positive while that of concave lens is taken as negative.

**Q23: Derive lens formula for a thin convex lens.**
**(BISE Kohat 2019)** ایک پتلے محدب عدسے کا کلیہ اخذ کریں۔

Ans. The thin lens formula is the relationship between distance of object, distance of image and focal length of the lens.

Derivation of Formula

Consider an object "AB" placed at right angle to the axis of the lens, as shown in the figure. Let two rays "AC" and "AO" starts from "A" and meet each other at point "A'" after refraction. Thus "A'B'" becomes the image of the object "AB". Now in $\Delta AOB$ and $\Delta A'OB'$, we have,



$< ABO = < A'B'O$ [both are right angles]

And $< AOB = < A'OB'$ [both are opposite angles)

So both triangles are equal, thus we have,

$$\frac{AB}{A'B'} = \frac{OB}{OB'} \text{ ------- } (1)$$

Now in $\Delta COF$ and $\Delta A'B'F$, we have,

$< COF = < A'B'F$ [both are right angles)

And $< CFO = < A'FB'$ [both are opposite angles)

So both triangles are equal, thus we have,

$$\frac{OC}{A'B'} = \frac{OF}{B'F} \text{ ------- } (2)$$

Here we have,

$OC = AB$ and $B'F = OB' - OF$

So equation (2) $\Rightarrow$

$$\frac{AB}{A'B'} = \frac{OF}{(OB' - OF)} \text{ ------- } (3)$$

Now comparing equation (1) and (3), we get,

$$\frac{OB}{OB'} = \frac{OF}{(OB' - OF)} \text{ ------- } (4)$$

Here $OB = d_o, OB' = d_i$ and $OF = f$,

So equation (4) $\Rightarrow$

$$\frac{d_o}{d_i} = \frac{f}{(d_i - f)} \text{ [by cross multiplication]}$$

$$\Rightarrow \quad d_o(d_i - f) = d_i f$$

$$\Rightarrow \quad d_o d_i - d_o f = d_i f \text{ ------- } (5)$$

Now dividing both sides of equation (v) by "$d_o d_i f$", we get

$$\frac{d_o d_i}{d_o d_i f} - \frac{d_o f}{d_o d_i f} = \frac{d_i f}{d_o d_i f}$$

$$\Rightarrow \quad \frac{1}{f} - \frac{1}{d_i} = \frac{1}{d_o} \Rightarrow \boxed{\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}} \text{ ------- } (6)$$

If we put $d_o$ = distance of object = p and $d_i$ = distance of image = q then equation (6) can be also written as,

$$\boxed{\frac{1}{f} = \frac{1}{p} + \frac{1}{q}} \text{ ——— } (7)$$

Equation (6) and (7) represents thin lens formula for a convex lens.

**Q24: Define linear magnification. طولی تکبیر سے کیا مراد ہے؟**

Ans. "The ratio between size of image and size of the object is known as linear magnification." i.e.,

$$Magnification = \frac{Size\ of\ image}{Size\ of\ object}$$

$$\Rightarrow \boxed{M = \frac{A'B'}{AB}}$$

(OR) $Magnification = \dfrac{Distance\ of\ image}{Distance\ of\ object}$

$\Rightarrow M$ [illegible]

OR $\boxed{M = \dfrac{d_i}{d_o}}$ or $\boxed{M = \dfrac{h_i}{h_o}}$

As the magnification represents a ratio, so it has no unit.

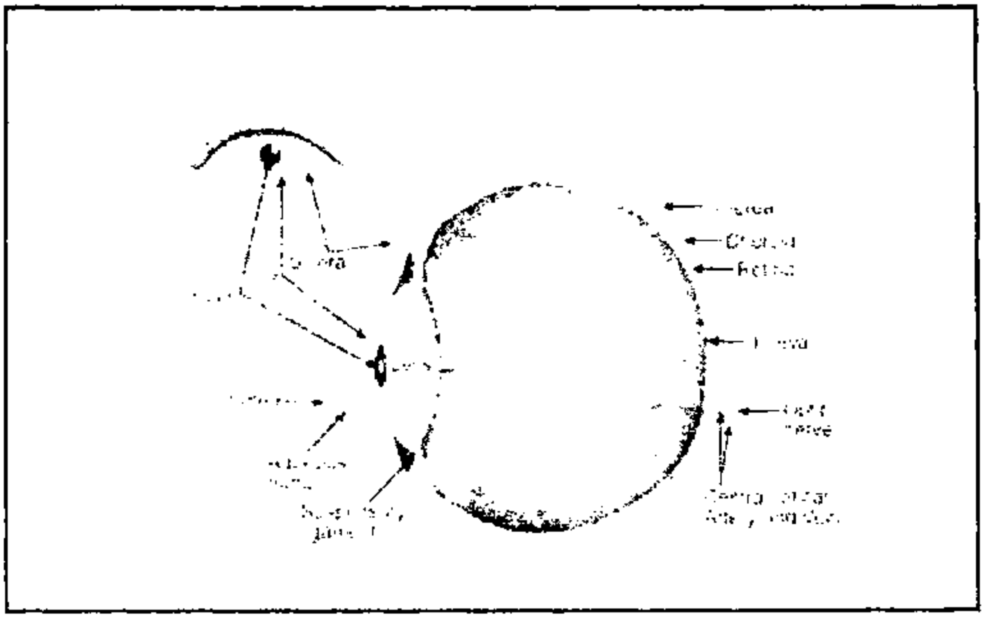
**Q1: Describe the features of a human eye that allows it to see. انسانی آنکھ کی خصوصیات اور دیکھنے کا عمل بیان کریں**

Ans. <u>Human Eye (انسانی آنکھ)</u>:

Human eye is a precious gift of Allah. We can see, study and enjoy the coloured world with the help of eyes. The eye works like a camera.

## Various Part of Eye (آنکھ کے مختلف حصے):

The various parts of eye and their functions are given below:



### 1. Convex Lens (محدب عدسہ):

The convex lens system of the eye forms a small inverted image of an object in front of it.

### 2. Iris (آئرس):

It is situated in the middle of eye. It consists of pupil and controls the amount of light going into the eye.

### 3. Pupil (پتلی):

The size of pupil in controlled by iris. The pupil help us to see objects in darkness as well as in light. It grows larger in darkness to see objects clearly and contracts in bright light.

### 4. Cornea and Citreous (کارنیہ اور ویٹریس):

The cornea and vitreous which is a waterly fluid are used for focusing the rap of light.

5· Retina (ریٹینا):

The retina acts like a screen on which inverted image is formed·

6· Optic Nerve (عصری اعصاب):

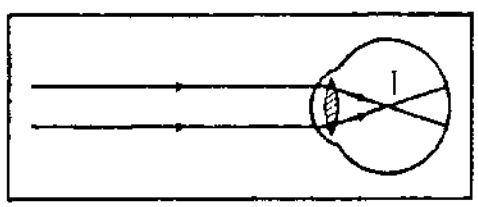
The optic nerve carries the image from the retina to the brain· The brain interprets the image and gives an erect view of the object·

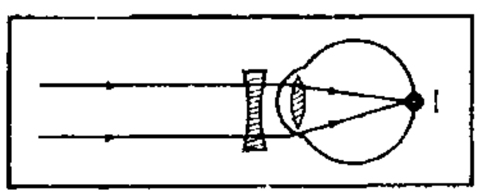
> **Q26: How the defects in the eye like short sightedness and long sightedness be corrected by using lenses? (OR) What are the chief defects of vision? How can each defect be corrected?**
>
> آنکھ میں پائے جانے والے نقائص جیسے قریب نظری اور بعید نظری کو عدسے کے ذریعے کے دور کیا جا سکتا ہے؟
>
> (یا) آنکھ کے بارے نقائص بیان کریں۔ نیز یہ بتائیں کہ ان نقائص کو کس طرح درست کیا جا سکتا ہے؟

Ans· There are certain defects of vision, which occurs due to lack [غیر موجودگی] of coordination [ربط] among various parts of the eye· These defects are given below:

1) Short-Sightedness [قریب نظری]

This defect [نقص] is also known as myopia· In this type of defect, the eye can see near objects clearly but the distant [دور] objects are not seen clearly· In such a case, the lens of the eye is more convergent than that of normal eye· So the parallel rays of light coming from distant object are focused just in front of the retina· For the correc-

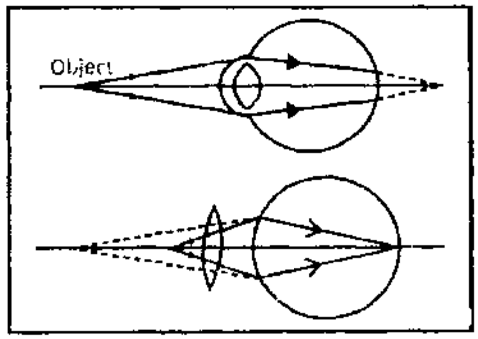


tion of this defect, a concave lens is placed in front of the eye. This combination of the two lenses enables the image to be formed on the retina.

2) Long Sightedness [بعید نظری]

This defect is also known as hypermetropia. In this case, the eye can see distant objects clearly but nearer objects are not seen clearly. In this case the lens of the eye is less convergent than that of the normal eye. So




the rays of light coming from the near object are focused beyond the retina.

This type of defect can be corrected by placing a convex lens in front of the eye. By doing so, the image will be formed on the retina of the eye.

**Q27: What is a simple microscope? Using a ray diagram, explain its working, angular magnification and magnifying power.**

سادہ مائیکروسکوپ سے کیا مراد ہے؟ شعاع والی ڈایاگرام کے ذریعے اس کے کام کرنے کے اصول اور تکبیری طاقت کی وضاحت کریں۔

Ans. Simple Microscope:

(BISE Swat, Kohat, Bannu, Mardan 2019)

"A convex lens of small focal length is known as simple microscope. It is also known as magnifying glass."

Principle of Working:

The principle of simple microscope is that, when an

object is placed between a convex lens and its principal focus, then an erect, virtual and magnified image will be formed on the same side of the object.

### Working of Simple Microscope

The simple microscope is an ordinary convex lens of small focal length which is held closer to the eye for magnifying the image. The microscope brings the object closer to the eye, so we can see the object clearly.

Now consider an object "AB" is placed between the lens and its focus, as shown in the figure. The lens forms a magnified, virtual and erect image "A'B'" of the object "AB" which can be seen clearly by an eye which is held closer to the lens.

### Angular Magnification

The ratio of angular size of final image produced by optical instrument to the reference angular size of object seen without optical instrument. [The reference angular size is the angular size of the object when seen without the instrument]. So

$$\text{Angular magnification} = \left( \frac{\text{Angular size of final image produced by optical instrument}}{\text{Reference angular size of object}} \right)$$

$$\Rightarrow \quad M_\theta = \frac{\theta'}{\theta} \quad \text{--- --- (1)}$$

### Calculation of $\theta$

Consider an object of size $AB = h_o$ placed at a distance "N" from eye without using magnifying glass,

as shown in the figure (a).

Now in figure (a), we have

$$\tan\theta = \frac{Perpendicular}{Base}$$

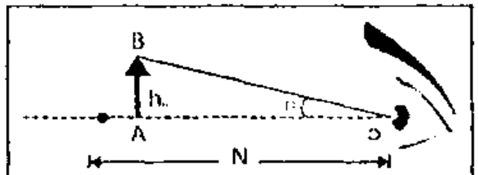


Fig (a)

$$\Rightarrow \quad \tan\theta = \frac{h_o}{N} \text{ ——— } (2)$$

Calculation of θ'

Let the object is placed inside the focal length of a convex lens as shown in the figure (b).

Now in figure (b), we have

$$\tan\theta' = \frac{h_o}{d_o} \text{ —— } (3)$$

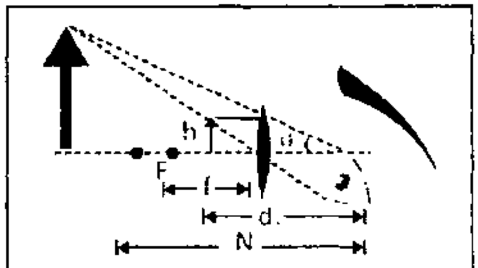


Fig (b)

Here "θ" and "θ'" are very small angles, so we put $\tan\theta = \theta$ and $\tan\theta' = \theta'$, so equation (2) and equation (3) can be written as,

$$\theta = \frac{h_o}{N} \text{ ——— } (4)$$

And $\theta' = \frac{h_o}{d_o}$ ——— (5)

Putting equation (4) and (5) in equation (1), we get,

$$M_\theta = \frac{\left(\frac{h_o}{d_o}\right)}{\frac{h_o}{N}} = \frac{h_o}{d_o} \times \frac{N}{h_o}$$

$$\Rightarrow \quad M_\theta = \frac{N}{d_o} \text{ ——— } (6)$$

Now according to thin lens formula, we have,

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\Rightarrow \quad \frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} \text{ ——— } (7)$$

Putting equation (7) in equation (6), we get,

$$\boxed{M_\theta = N\left[\frac{1}{f} - \frac{1}{d_i}\right]} \text{ ——— } (8)$$

Equation (8) represents the angular magnification or magnifying power of simple microscope.

Special Cases

Case 1: For nearer image, we put

$d_i = -N$

[The negative sign shows that the image lies to the left of lens and is virtual.]

So equation (8) becomes,

$$M_\theta = N\left[\frac{1}{f} - \frac{1}{(-N)}\right] = N\left[\frac{1}{f} + \frac{1}{N}\right]$$

$$\Rightarrow \quad M_\theta = \frac{N}{f} + \frac{N}{N} = \frac{N}{f} + 1$$

$$\Rightarrow \quad \boxed{M_\theta = \frac{N}{f} + 1} \text{ ——— } (9)$$

Equation (9) represents the magnifying power of simple microscope for nearer image.

Case 2: For farthest image, we put

$d_i = \infty$, so equation (8) becomes,

$$M_\theta = N\left[\frac{1}{f} - \frac{1}{\infty}\right]$$

$$\Rightarrow \quad M_\theta = N\left[\frac{1}{f} - 0\right] \qquad \left[\frac{1}{\infty} = 0 \text{ and } \frac{1}{0} = \infty\right.$$

$$\Rightarrow \quad \boxed{M_\theta = \frac{N}{f}} \text{ ——— } (10)$$

Equation (10) represents the magnifying power of simple microscope.

## Uses of Simple Microscope

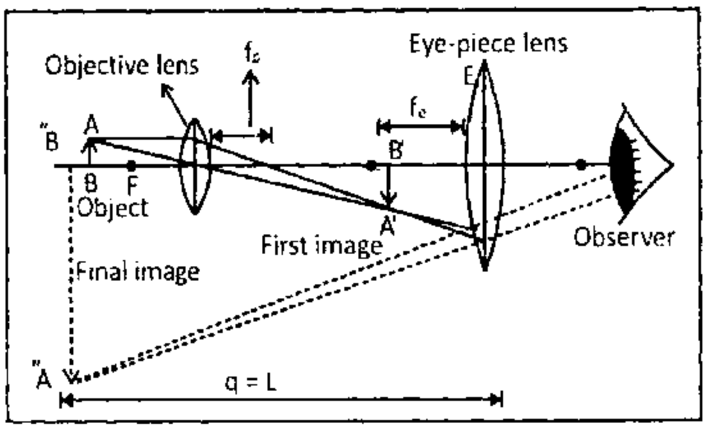
1. It is used in optical devices as an eye-piece.
2. It is used to examine slides in laboratory.
3. It is used for finding the defect in sensitive devices.
4. It is used for matching the finger prints in detection departments.

**Q28: Write a note on compound microscope.**

Ans. The compound microscope is an optical instrument which is used for observing small objects clearly.

## Construction

It consists of two convex lenses as shown in the figure. One of these lenses posses small focal length and is known as objective lens. The other lens posses large focal length and is known as eye-piece.




## Working [کارگزاری]

The objective lens form a real, inverted image "A'B' ", if an object "AB" placed beyond the focus of objective. This image "A'B' " acts as a real object for the eye-piece, which produces final virtual and magnified image "A"B" ", as shown in the figure.

Now the magnifying power of compound microscope

is equal to the product of magnifying power of objective and magnifying power of eye-piece i.e.

$$M = M_o \times M_e \text{ ——— } (1)$$

Now for objective, we have,

$$M_o = \frac{A''B''}{AB}$$

$$\Rightarrow \quad M_o = \frac{q}{p} \text{ ——— } (2) \qquad [A''B'' = q,\ AB = p$$

Here, $p =$ focal length of objective $= f_o$

And $q =$ distance of image $= d_i$

Thus equation (2) becomes,

$$M_o = \frac{-d_i}{f_o} \text{ ——— } (3)$$

The negative sign shows that the image is inverted. Here the eye-piece behave like simple microscope, so its magnifying power will be,

$$M_e = \frac{N}{f_e} \text{ ——— } (4)$$

Putting equations (3), (4) in equation (1), we get,

$$\boxed{M = -\frac{d_i}{f_o} \times \frac{N}{f_e}} \text{ ——— } (5)$$

Equation (5) represents the magnifying power of compound microscope. This equation shows that, the magnifying power of compound microscope can be increased by using lenses of smaller focal length.

**Q29: What is telescope? Using a ray diagram explain its working, angular magnification and magnifying power.**

دور بین کیا ہوتا ہے؟ شعاع والے ڈایاگرام کے ذریعے اس کے کام کرنے کے اصول اور تکبیری طاقت کی وضاحت کریں۔

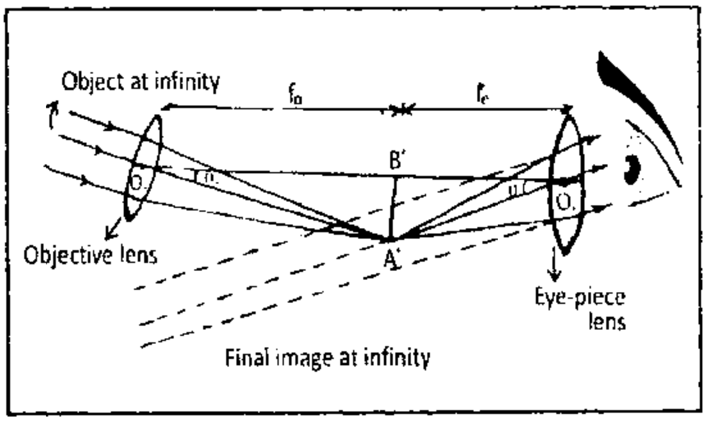
Ans. **Telescope [دوربین]**

It is optical instrument which is used to see heavenly bodies and other distant objects clearly.

**Construction**

It consists of two convex lenses such that one lens is known as objective lens and the other is known as eye-piece, as shown in the figure.

**Working [طریقہ کار]**




The objective lens forms a real, inverted and diminished image "A'B'" of an object "AB" which is placed at infinity. This image behaves as a real object for the eye-piece and it produces final, virtual and magnified image at infinity. Under such conditions, the telescope is said to be set for parallel rays or for infinity.

Now the magnifying power is given by,

$$M = \frac{\theta_i}{\theta_o} \text{ ——— } (1)$$

Now in $\Delta A'O_2B'$, we have,

$$\tan\theta_i = \frac{A'B'}{O_2B'} \Rightarrow \tan\theta_i = \frac{A'B'}{f_e} \text{ ——— } (2)$$

As $\theta_i <<$, so we put $\tan\theta_i = \theta_i$

So equation (2) $\Rightarrow$

$$\theta_i = \frac{A'B'}{f_e} \text{ ——— } (3) \qquad [O_2B' = f_e]$$

Similarly, $\theta_o = \frac{A'B'}{f_o}$ ——— (4) $\qquad \left[ \tan\theta_o = \frac{A'B'}{O_1B'} \text{ and } O_1B' = f_o \right.$

Putting equations (3), (4) in equation (1),

$$M = \left(\frac{A'B'}{f_e}\right) / \left(\frac{A'B'}{f_o}\right)$$

$$\Rightarrow \quad M = \frac{A'B'}{f_e} \times \frac{f_o}{A'B'} \Rightarrow \boxed{M = \frac{f_o}{f_e}} \text{ ——— } (5)$$

$$\text{OR} \quad \boxed{M = -\frac{f_o}{f_e}} \text{ ——— } (6)$$

Equation (6) represents the magnifying power of telescope. The negative sign shows that the 1st image is inverted.

<u>Length of Telescope</u>

The distance between the two lenses gives us the length of telescope. i.e.,

$$L = \text{Distance between lenses } = f_o + f_e$$

$$\Rightarrow \quad \boxed{L = f_o + f_e} \text{ ——— } (7)$$

Equation (7) represents the length of telescope.

## Solution of Examples, Assignments

**Example 1:** The concave side of a spoon has a focal length of 5·00cm· Find the image distance for this "mirror" when the object distance is (a) 12·0cm, (b) 10·0cm, (c) 7·50cm, (d) 5·00cm and (e) 2·00cm·

**Solution:**

**Given data:** Focal length "f" = 5·00cm

(a) Object distance "$d_o$" = 12·0cm

(b) Object distance "$d_o$" = 10·0cm

(c) Object distance "$d_o$" = 7·50cm

(d) Object distance "$d_o$" = 5·00cm

(e) Object distance "$d_o$" = 2·00cm

**Required:** (a) Image distance "$d_i$" = ?

(b) Image distance "$d_i$" = ?

(c) Image distance "$d_i$" = ?

(d) Image distance "$d_i$" = ?

(e) Image distance "$d_i$" = ?

**Calculation:** (a) We know that,

$$\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i} \Rightarrow \frac{1}{d_i}=\frac{1}{f}-\frac{1}{d_o}$$

$$\Rightarrow \quad \frac{1}{d_i}=\frac{d_o-f}{fd_o} \Rightarrow d_i=\frac{fd_o}{d_o-f} \longrightarrow (i)$$

Put $d_o = 12cm$ and $f = 5cm$ in equation (i)

$$d_i=\frac{5\times 12}{12-5}=\frac{60}{7}=8{\cdot}57cm=8{\cdot}6cm$$

$$\Rightarrow \quad \boxed{d_i=8{\cdot}6cm}$$

(b) Put $f = 5cm, d_o = 10cm$ in equation (i), we get,

$$d_i = \frac{5\times 10}{10-5} = \frac{50}{5}cm = 10cm$$

$\Rightarrow$ $\boxed{d_i = 10cm}$

(c) Put $f = 5cm$ and $d_o = 7{\cdot}50cm$ in equation (i), we get

$$d_i = \frac{5\times 7{\cdot}50}{7{\cdot}50-5} = \frac{37{\cdot}5}{2{\cdot}5}cm = 15cm$$

$\Rightarrow$ $\boxed{d_i = 15cm}$

(d) Put $f = 5cm, d_o = 5cm$ in equation (i), we get,

$$d_i = \frac{5\times 5}{5-5} = \frac{25}{0} = \infty$$

$\Rightarrow$ $\boxed{d_i = \infty}$

(e) Put $f = 5cm, d_o = 2cm$ in equation (i), we get,

$$d_i = \frac{5\times 2}{2-5} = \frac{10}{-3} = -3{\cdot}33cm$$

$\Rightarrow$ $\boxed{d_i = -3{\cdot}33cm}$

Here the negative sign shows that the image is formed on the other side of the mirror.

> Assignment 1: A dentist uses a concave mirror with focal length 2·0cm to examine some teeth. If the tooth under examination is 1·1cm high and mirror is placed at 0·9cm. Calculate the distance of image formed, the height of the image and magnification.

Solution:

Given data: Focal length $= f = 2cm$

Height of tooth (object) $= h_o = 1{\cdot}1cm$

Distance of object $= d_o = 0{\cdot}9cm$

Required: (a) Distance of image $= d_i = ?$

(b) Height of image $= h_i = ?$

(c) Magnification = $M$ = ?

**Calculation:** (a) We know that,

$$\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i} \Rightarrow \frac{1}{d_i}=\frac{1}{f}-\frac{1}{d_o}$$

$$\Rightarrow \quad d_i=\frac{fd_o}{d_o-f} \longrightarrow (i)$$

Put $f = 2cm$ and $d_o = 0{\cdot}9cm$ in equation (i), we get,

$$d_i=\frac{2\times 0{\cdot}9}{0{\cdot}9-2}=\frac{1{\cdot}8}{-1{\cdot}1}=-1{\cdot}64cm$$

$$\Rightarrow \quad \boxed{d_i=-1{\cdot}64cm}$$

(b) We know that, $\frac{h_i}{h_o}=\frac{d_i}{d_o}$

$$\Rightarrow \quad h_i=\frac{d_i\times h_o}{d_o}$$

$$\Rightarrow \quad h_i=\frac{-1{\cdot}64\times 1{\cdot}1}{0{\cdot}9} \Rightarrow \boxed{h_i=-2{\cdot}0cm}$$

(c) As $M=\frac{h_i}{h_o}=\frac{-2{\cdot}0cm}{1{\cdot}1cm}=-1{\cdot}8$

$$\Rightarrow \quad \boxed{M=-1{\cdot}8}$$

> Example 2: An external rearview car mirror is convex with a radius of curvature of 16·0m· Determine (a) the focal length of the mirror, (b) location of the image and (c) its magnification for an object 10·0m from the mirror·

**Solution:**

**Given data:** Object distance = $d_o$ = 10m

Radius of curvature = $R$ = 16·0m

**Required:** (a) Focal length = "$f$" = ?

(b) Image distance = "$d_i$" = ?

(c) Magnification = "$M$" = ?

**Calculation:** (a) Radius of curvature and focal length for convex mirror are related by equation

$$f = -\frac{1}{2}R \text{ ——— } (1)$$

Putting the value of "R" in equation (1), we get,

$$f = -\frac{1}{2} \times 16m \Rightarrow \boxed{f = -8m}$$

Focal length of convex mirror is negative

(b) We know that, $\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$

$$\Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{d_o - f}{fd_o}$$

$$\Rightarrow \frac{1}{d_i} = \frac{d_o - f}{fd_o} \Rightarrow d_i = \frac{fd_o}{d_o - f} \text{ ——— } (2)$$

Putting the values of "f" and "$d_o$" in equation (2), we get,

$$d_i = \frac{(-8) \times 10}{10 - (-8)} = \frac{-80}{(10+8)} m = \frac{-80}{18} m$$

$$\Rightarrow \boxed{d_i = -4.4m}$$

(c) Magnification of convex mirror is given by,

$$M = -\frac{d_i}{d_o} \text{ ——— } (3)$$

Putting the values of "$d_i$" and "$d_o$" in equation (3)

$$M = -\frac{(-4.4)m}{10m} \Rightarrow \boxed{M = 0.44}$$

Assignment 2: A convex security mirror in a warehouse has a -0.50m focal length. A 2.0m tall forklift is 5.0m from the mirror. What is the image position and image height?

**Solution:**

Given data: Focal length of convex mirror = $f$ = -0.50m

Height of object $= h_o = 2m$

Distance of object from mirror $= d_o = 5m$

Required: (a) Image position $= d_i = ?$

(b) Height of image $= h_i = ?$

Calculation: (a) We know that,

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

$$\Rightarrow \quad \frac{1}{d_i} = \frac{d_o - f}{fd_o} \Rightarrow d_i = \frac{fd_o}{d_o - f} \text{ ——— } (1)$$

Putting the values of "f" and "$d_o$" in equation (1), we get

$$d_i = \frac{-0.50 \times 5}{5-(-0.50)} = \frac{-2.5}{5+0.50} = \frac{-2.5}{5.5} m$$

$$\Rightarrow \quad \boxed{d_i = -0.45m}$$

The image is virtual and formed behind the mirror.

(b) We know that,

$$\frac{h_i}{h_o} = \frac{d_i}{d_o} \Rightarrow \quad h_i = \frac{d_i \times h_o}{d_o} \text{ ——— } (2)$$

Putting the values in equation (2), we get

$$\Rightarrow \quad h_i = \frac{-0.45 \times 2}{5} = \frac{-0.9}{5} m \Rightarrow \boxed{h_i = -0.18m}$$

**Example 3: What is speed of light in water having index of refraction as 1.33?**

Solution:

Given data:

Speed of light in vacuum $= c = 3.00 \times 10^8 \, m/s$

Index of refraction for water $= n = 1.33$

Required: Speed of light in water $= v = ?$

Calculation: We know that, the index of refraction is given by,

$$n = \frac{c}{v} \Rightarrow v = \frac{c}{n} \text{ ——— } (1)$$

Putting the values in equation (1), we get,

$$v = \left[\frac{3\times10^8}{1\cdot33}\right] m/sec = \boxed{v = 2\cdot26\times10^8\ m/sec}$$

$$\boxed{v = 2\cdot26\times10^8\ m/sec}$$ Answer

**Assignment 3:** If the speed of light in kerosene oil is $2\cdot08 \times 10^8$ m/s, calculate the index of refraction.

Solution:

Given data: Speed of light in kerosene oil $= v = 2\cdot08\times10^8\ m/sec$

Speed of light in vacuum $= c = 3\times10^8\ m/sec$

Required: Index of refraction = n = ?

Calculation: We know that,

$$n = \frac{c}{v} \text{ ——— } (1)$$

Putting the values in equation (1), we get

$$n = \frac{c}{v} = \frac{3\times10^8\ m/sec}{2\cdot08\times10^8\ m/sec} \Rightarrow \boxed{n = 1\cdot44}$$

$$\boxed{n = 1\cdot44}$$ Answer

**Example 4:** Light travels from crown glass ($n_g = 1\cdot52$) into water ($n_w = 1\cdot33$). The angle of incidence in crown glass is $40\cdot0°$. What is the angle of refraction in water?

Solution:

Given data:

Index of refraction for crown glass $= "n_g" = 1\cdot52$

Index of refraction for water $= n_w = 1\cdot33$

Angle of incidence $= \theta_g = 40\cdot0^\circ$

**Required:** Angle of refraction $= \theta_w = ?$

**Calculation:** According to Snell's law, we have,

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\Rightarrow \quad n_g \sin\theta_g = n_w \sin\theta_w$$

$$\Rightarrow \quad \sin\theta_w = \frac{n_g \sin\theta_g}{n_w} \longrightarrow (i)$$

Putting the values of equation (i), we get,

$$\sin\theta_w = \frac{1\cdot52 \times \sin 40^\circ}{1\cdot33} = \frac{1\cdot52 \times 0\cdot643}{1\cdot33}$$

$$\Rightarrow \quad \sin\theta_w = 0\cdot735 \quad \Rightarrow \theta_w = \sin^{-1}(0\cdot735) = 47\cdot3^0$$

$\boxed{\theta_w = 47\cdot3^\circ}$ Answer

> Assignment 4: Find the index of refraction for medium 2, if medium 1 is air with index of refraction $n_a = 1\cdot00$, the incident angle is $30\cdot0^\circ$ and the angle of refraction is $22\cdot0^\circ$. Compare the result with the table and indentify the nature of medium 2.

**Solution:**

**Given data:**

Refractive index of air $= n_1 = 1\cdot00$

Angle of incidence $= \theta_1 = 30\cdot0^\circ$

Angle of refraction $= \theta_2 = 22\cdot0^\circ$

**Required:** Refractive index of 2nd medium $= n_2 = ?$

**Calculation:** We know that

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\Rightarrow \quad n_2 = \frac{n_1 \sin\theta_1}{\sin\theta_2} \longrightarrow (i)$$

Putting the values in equation (i), we get,

$$n_2 = \frac{1{\cdot}00 \times \sin 30^\circ}{\sin 22^\circ} = \frac{1{\cdot}00 \times 0{\cdot}5}{0{\cdot}375} = 1{\cdot}33$$

$\Rightarrow$ $\boxed{n_2 = 1{\cdot}33}$

*If we compare this value of "$n_2$" in the table, it match with refractive index of water, so the 2nd medium is water.*

**Example 5:** *Find the critical angle for light traveling from glass (n = 1·502) to (a) air (n = 1·002) and (b) water (n = 1·332).*

*Solution:*

*Given data:*

Index of refraction for ordinary glass $= n_g = 1{\cdot}502$

(a) Index of refraction for air $= n_a = 1{\cdot}002$

(b) Index of refraction for water $= n_w = 1{\cdot}332$

*Required:* (a) Critical angle $= \theta_c = ?$ for part (a)

(b) Critical angle $= \theta_c = ?$ for part (b)

*Calculation:* We know that,

$$\sin\theta_c = \frac{n_2}{n_1} \longrightarrow (i)$$

(a) For glass and air, equation (i) can be written as,

$$\sin\theta_c = \frac{n_a}{n_g} = \frac{1{\cdot}002}{1{\cdot}502} = 0{\cdot}667$$

$\Rightarrow$ $\sin\theta_c = 0{\cdot}667 \Rightarrow \theta_c = \sin^{-1}(0{\cdot}667) = 41{\cdot}8^\circ$

$\boxed{\theta_c = 41{\cdot}8^\circ}$ Answer

(b) For glass and water, equation (i) can be written as,

$$\sin\theta_c = \frac{n_w}{n_g} = \frac{1{\cdot}332}{1{\cdot}502} = 0{\cdot}887$$

$\Rightarrow$ $\sin\theta_c = 0{\cdot}887 \Rightarrow \theta_c = \sin^{-1}(0{\cdot}887) = 62{\cdot}5^\circ$

$\boxed{\theta_c = 62.5^\circ}$ Answer

**Assignment 5:** What is the critical angle for light traveling in a polystyrene (a type of plastic with index of refraction for polystyrene as 1·49) pipe surrounded by air (take index of refraction of air to be 1·00)?

**Solution:**

**Given data:**

Refractive index of polystyrene $= n_1 = 1.49$

Refractive index of air $= n_2 = 1.00$

**Required:** Critical angle $= \theta_c = ?$

**Calculation:** We know that,

$$\sin\theta_c = \frac{n_2}{n_1}$$

$$\Rightarrow \quad \sin\theta_c = \left(\frac{1.00}{1.49}\right) = 0.671$$

$$\Rightarrow \quad \sin\theta_c = 0.671 \Rightarrow \theta_c = \sin^{-1}(0.671) = 42.2^0$$

$\boxed{\theta_c = 42.2^\circ}$ Answer

**Example 6:** A converging lens of focal length 10·0cm forms images of an object situated at various distances. (a) If the object is placed 30·0cm from the lens, locate the image, state whether it's real or virtual, and find its magnification. Repeat the problem (b) when the object is at 20·0cm and (c) when the object is 15·0cm from the lens (d) when the object is 10·0cm from the lens and (e) when the object is 5·00cm from the lens.

**Solution:**

**Given data:** Focal length $= "f" = 10.00\,cm$

(a) Object distance $= "d_o" = 30\cdot0cm$

(b) Object distance $= "d_o" = 20\cdot0cm$

(c) Object distance $= "d_o" = 15\cdot0cm$

(d) Object distance $= "d_o" = 10\cdot00cm$

(e) Object distance $= "d_o" = 5\cdot00cm$

**Required:**

(a) Image distance $= "d_i" = ?$, Magnification $= M = ?$

(b) Image distance $= "d_i" = ?$, Magnification $= M = ?$

(c) Image distance $= "d_i" = ?$, Magnification $= M = ?$

(d) Image distance $= "d_i" = ?$, Magnification $= M = ?$

(e) Image distance $= "d_i" = ?$, Magnification $= M = ?$

Calculation: We know that,

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\Rightarrow \quad \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{d_o - f}{fd_o} \Rightarrow d_i = \frac{fd_o}{d_o - f} \text{ —— } (1)$$

(a) Put $f = 10cm, d_o = 30cm$ in equation (i), we get,

$$d_i = \frac{10\times30}{30-10} = \frac{300}{20} \Rightarrow \boxed{d_i = 15cm}$$

Also magnification $= M = -\frac{d_i}{d_o}$ —— (2)

Putting the values in equation (2), we get,

$$M = -\frac{15cm}{30cm} \Rightarrow \boxed{M = -0\cdot5}$$

(b) Put $f = 10cm, d_o = 20cm$ in equation (1), we get,

$$d_i = \frac{10\times20}{20-10} = \frac{200}{10}cm \Rightarrow \boxed{d_i = 20cm}$$

Now putting the values in equation (2), we get,

$$M = -\frac{20}{20} \Rightarrow \boxed{M = -1}$$

(c) Put $f = 10cm, d_o = 15cm$ in equation (1), we get,

$$d_i = \frac{10 \times 15}{15-10} = \frac{150}{5}cm \Rightarrow \boxed{d_i = 30cm}$$

Now putting the values in equation (2), we get,

$$M = -\frac{30}{15} \Rightarrow \boxed{M = -2}$$

(d) Put $f = 10cm, d_o = 10cm$, in equation (1), we get,

$$d_i = \left(\frac{10 \times 10}{10-10}\right)cm \Rightarrow d_i = \frac{100}{0} \Rightarrow \boxed{d_i = \infty}$$

Now putting the values in equation (2), we get,

$$M = -\frac{\infty}{10} = \infty \Rightarrow \boxed{M = \infty}$$

(e) Put $f = 10cm, d_o = 5cm$ in equation (1), we get,

$$d_i = \frac{10 \times 5}{5-10} = \frac{50}{-5} \Rightarrow \boxed{d_i = -10cm}$$

Now putting the values in equation (2), we get,

$$M = -\frac{(-10)cm}{5cm} \Rightarrow \boxed{M = 2}$$

> Assignment 6: An object is placed 30·0cm in front of a converging lens and then 12·5cm in front of a diverging lens· Both lenses have a focal length of 10·0cm· For both cases, find the image distance and the magnification· Describe the images·

Solution:

Given data:

(a) Object distance from convex lens $= d_o = 30cm$

(b) Object distance from concave lens $= d_o = 12{\cdot}5cm$

Focal length = $f$ = 10cm

Required: (a) Image distance $= d_i = ?$ [for part (a)]

Magnification = $M$ = ? [for part (a)]

(b) Image distance $= d_i = ?$ [for part (b)]

Magnification = $M$ = ? [for part (b)]

*Calculation:* (a) We know that,

$$\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}$$

$$\Rightarrow \quad \frac{1}{d_i}=\frac{1}{f}-\frac{1}{d_o}=\frac{d_o f}{d_o f}\Rightarrow d_i=\frac{d_o f}{d_o-f} \text{ —— (1)}$$

Put $d_o=30cm, f=10cm$ in equation (1), we get,

$$d_i=\left(\frac{30\times 10}{30-10}\right)cm=\frac{300}{20}cm \Rightarrow \boxed{d_i=15cm}$$

Now magnification $=M=-\frac{d_i}{d_o}$

$$\Rightarrow \quad M=-\frac{15}{30} \Rightarrow \boxed{M=-0\cdot 5}$$

(b) Put $f=-10cm, d_o=12\cdot 5cm$ in equation (1), we get,

$$d_i=\left(\frac{12\cdot 5\times(-10)}{12\cdot 5-(-10)}\right)cm=\frac{-125}{12\cdot 5+10}cm=\frac{-125}{22\cdot 5}cm$$

$$\Rightarrow \quad \boxed{d_i=-5\cdot 56cm}$$

Now $M=\frac{-d_i}{d_o}=\frac{-(-5\cdot 56)cm}{12\cdot 5cm} \Rightarrow \boxed{M=0\cdot 445}$

> Example 7: A biologist with a near-point distance of N = 26cm, examines an insect wing through a magnifying glass whose focal length is 4·3cm· Find the angular magnification when the image produced by the magnifier is (a) at the near point and (b) at infinity·

*Solution:*

*Given data:*

Focal length of magnifying glass $= f = 4\cdot 3cm$
Near-point distance $= N = 26cm$
Object distance $= d_o = 1\cdot 1cm$

*Required:*

(a) Magnification for nearer image $= M_0 = ?$

(b) Magnification for farthest image= $M_0$ =?

Calculation: (a) For nearer image, the angular magnification is given by,

$$M_0 = \frac{N}{f} + 1 \text{ ——— } (1)$$

Putting the values in equation (1), we get,

$$M_0 = \frac{26}{4\cdot 3} + 1 = 6\cdot 0 + 1 \Rightarrow \boxed{M_0 = 7}$$

(b) For farthest image, the angular magnification is given by,

$$M_0 = \frac{N}{f} \text{ ——— } (2)$$

Putting the values in equation (2), we get,

$$M_0 = \frac{26}{4\cdot 3} \Rightarrow \boxed{M_0 = 6}$$

> Assignment 7: An 8cm focal length converging lens is used as "jeweler's loupe", which is a magnifying glass. Estimate the magnification (a) when the eye is relaxed, and (b) if the eye is focused its near point.

Solution:

Given data:

Focal length of converging lens = f = 8cm

Near point distance = N = 25cm

Required:

(a) Magnification [when eye is relaxed] = M = ?

(b) Magnification [when eye in focused at near point] = M = ?

Calculation: (a) The magnification in case of relaxed eye is given by,

$$M = \frac{N}{f} \text{ ——— } (1)$$

Putting the values in equation (1), we get,

$$M = \frac{25cm}{8cm} = 3{\cdot}12 = 3 \text{ times}$$

$\Rightarrow$ $\boxed{M = 3 \text{ times}}$

(b) The magnification, when eye is focused at its near point is given by,

$$M = \frac{N}{f} + 1 \text{ ——— } (2)$$

Putting the values in equation (2), we get,

$$M = \frac{25}{8} + 1 = \frac{25}{8} + 1$$

$\Rightarrow$ $M = 3{\cdot}12 + 1 = 4{\cdot}12 = 4$

$\Rightarrow$ $\boxed{M = 4 \text{ times}}$

**Example 8:** In biology class, a student with a near point distance of N = 25cm uses a microscope to view an amoeba. If the objective has a focal length of 1·0cm, the eye piece has a focal length of 2·5cm, and the amoeba is 1·1cm from the objective, what is the magnification produced by the microscope?

Solution:

Given data:

Focal length of eye piece = $f_e = 2{\cdot}5cm$

Focal length of objective = $f_o = 1{\cdot}0cm$

Near-point distance= $N = 25cm$

Objective distance = $d_o = 1{\cdot}1cm$

Required: Total magnification = $M$ = ?

Calculation: The magnifying power of compound mi-

croscope is given by,

$$M = \frac{-d_i}{f_o} \times \frac{N}{f_e} \text{———} (1)$$

Here "$d_i$" is unknown, so we first calculate "$d_i$" by lens formula

$$\frac{1}{f_o} = \frac{1}{d_i} + \frac{1}{d_o} \Rightarrow \frac{1}{d_i} = \frac{1}{f_o} - \frac{1}{d_o}$$

$$\Rightarrow \quad \frac{1}{d_i} = \frac{d_o - f_o}{f_o d_o} \Rightarrow d_i = \frac{f_o d_o}{d_o - f_o}$$

$$\Rightarrow \quad d_i = \left(\frac{1 \times 1\cdot1}{1 - 1\cdot1}\right) cm \Rightarrow \boxed{d_i = 11cm}$$

Now putting the values of $d_i$, $N$, $f_o$ and $f_e$ in equation (1), we get,

$$M = -\frac{11 \times 25}{1 \times 2\cdot5} \Rightarrow \boxed{M = -110}$$

> Assignment 8: If the focal length of the eye piece is increased, does the magnitude of the magnification increases or decreases? Check your response by calculating the magnification when the focal length of the eye piece is 3·5cm·

Solution: Here we use the data given in example 12·8, i·e· focal length of objective $= f_o = 1\cdot0cm$

Near point distance $= N = 25cm$

Object distance $= d_o = 11cm$

Focal length of eye-piece in assignment (12·8) $= f_e = 3\cdot5cm$

Required:

(a) Effect on magnification = ?

(b) Magnification = M = ?

Calculation: We know that magnification of compound microscope is given by,

$$M = -\frac{d_i}{f_o} \times \frac{N}{f_e} \text{ —— } (1)$$

Equation (1) shows that the magnification of compound microscope is inversely proportional to the focal length of eye-piece "$f_e$". i.e. if the focal length of eye-piece is increased then the magnification will decreased and vice versa.

(b) Putting the values in equation (1), we get,

$$M = -\frac{11cm}{1.0cm} \times \frac{25cm}{3.5cm}$$

$\Rightarrow \quad M = -78.6 = 79 \Rightarrow \boxed{M = -79}$

> Example 9: The largest optical refracting telescope in the world is located at the Yerkes Observatory in Wisconsin. The objective lens has a focal length of 19m, and the eye piece has a focal length of 10cm. (a) Calculate the total magnifying power of this telescope. (b) Estimate the length of the telescope.

Solution:

Given data:

Focal length of objective $= f_o = 10cm = 0.10m$

Focal length of eye piece $= f_e = 19m$

Required:

(a) Angular magnification $= M_\theta = ?$

(b) Approximate length $= L = ?$

Calculation:

(a) The magnifying power of telescope is given by,

$$M_\theta = \frac{-f_o}{f_e} \text{ —— } (1)$$

Putting the values in equation (1), we get,

$$M_0 = \frac{-19m}{0.10m} \Rightarrow \boxed{M_0 = -190}$$

(b) The length of telescope is given by,

$$L = f_o + f_e \text{ ——— } (2)$$

Putting the values in equation (2), we get,

$$L = (0.10 + 19)m = 19.1m \approx 19m$$

$\boxed{L = 19m}$ Answer

**Assignment 9: An astronomical telescope has the following specifications: $f_o$ = 985mm and $f_e$ = 5.00mm. From these data points, find (a) the angular magnification and (b) the approximate length of this telescope.**

Solution:

Given data:

Focal length of objective = $f_o = 985mm$,

Focal length of eye-piece = $f_e = 5mm$

Required:

(a) Angular magnification $= M_0 = ?$

(b) Length of telescope = $L$ = ?

Calculation:

(a) We know that, the angular magnification of telescope is given by,

$$M_0 = -\frac{f_o}{f_e} = \frac{-985mm}{5mm}$$

$\Rightarrow \boxed{M_0 = -197}$

(b) We also know that, the length of telescope is given by,

$$L = f_o + f_e$$

$\Rightarrow L = 985mm + 5mm \Rightarrow \boxed{L = 990mm}$

## Exercise

Q1: Choose the correct answer.

1. If the angle of incidence is 30° the angle of reflection will be:
   a. 30°✓ b. 45°
   c. 90° d. 210°
2. When 'r' is the radius of curvature of concave mirror, real diminished image will be formed when the object is at:
   a. $d_o > r$ ✓ b. $d_o = r$
   c. $r > d_o > f$ d. $d_o = f$
3. The focal length of convex mirror with radius of curvature 10cm is:
   a. +10cm b. +5cm
   c. -10cm d. -5cm ✓

Solution:

R = 10cm, the focal length of convex mirror is given by,

$$f = -\frac{1}{2}R = -\frac{1}{2} \times 10cm \Rightarrow f = -5cm$$

4. An object is placed 7cm from a concave mirror whose radius of curvature is 10cm, the image formed will be:
   a. Real and upright b. Virtual and upright
   c. Real and inverted✓ d. Virtual and inverted
5. Which one of the following materials will refract light more?
   a. Water b. Glass
   c. Air d. Diamond✓
6. A convex lens with focal length 8.00cm has

the power of lens:

a. 2.05D b. 4.00D

c. 12.5D✓ d. 16.0D

**Solution:**

$f = 8cm = 0.08m$

$$\text{Power of lens} = D = \frac{1}{f} = \frac{1}{0.08} = 12.5D$$

7. If the distance from your eye's lens to the retina is shorter than for a normal eye, you will struggle to see objects that are......

a. Nearby✓ b. Colorful

c. Far away d. Moving fast

8. Who benefits more from using a magnifying glass, a person whose near point is located at a distance away from the eyes of......

a. 75cm b. 50cm

c. 35cm d. 25cm✓

9. The human eye forms the image of an object at its:

a. Iris b. Retina✓

c. Pupil d. Cornea

## Conceptual Questions

Give a brief response to the following questions:

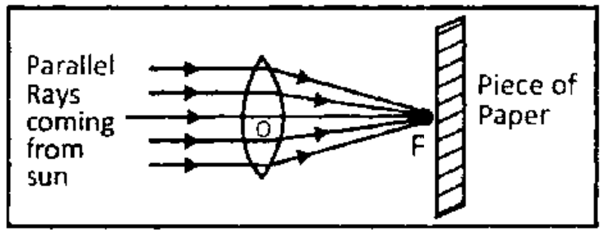
**Q1: Which type of lens would you use to start fire from light from sun concave or convex, would work best? At what distance from the lens should the paper be held for best results?**

Ans. We will use a convex lens to start fire using sun rays.

*Reasons and Explanation:*

*A convex lens focuses the parallel sun rays to a single point after refraction through the lens. The focusing point is known as principle focus "F".*

*Take a convex lens and place the paper at a distance equal to the focal length of the lens. The lens converge sunlight to the principle focus, i.e. on the paper. After some time the paper heat up and catches fire instantly. For best results, the paper should be placed at the focal point of the lens and a lens of larger aperture should be used. Larger lenses collect more sun rays and will be more powerful.*




> *Q2: If a concave mirror produces a real image, is the image necessarily inverted? Explain.*

*Ans. If a concave mirror produces a real image, then the image will be inverted.*

*Reasons and Explanation:*

*A real image is an image formed when light rays actually pass through the point where the image is formed. This real image can be obtained on a piece of paper (screen) placed at that point whereas virtual image occurs when rays only appear to converge real. Real image can be produced by a concave mirror only if the object is placed away from the focal point of the mirror. This real image will always be inverted i.e. upside down. This is because a*

concave mirror focuses light rays, thus inverting the real image.

**Q3: Are rearview mirrors using in cars concave or convex?**

Ans. The convex lenses are used in cars to see the rear view.

Reasons and Explanation:

Convex mirrors are useful for rare view in vehicles, as they provide a larger field of view than the concave mirrors. Convex mirrors give erect, virtual and diminished image of distant objects with a wider field of view.

Concave mirrors, on the other hand form inverted images of the distant objects with a smaller field of view. The inverted images around be hard to understand. Thus for a broader field of view, erect and clear images, convex mirrors are most suitable than concave mirrors.

**Q4: A magician during a show makes a glass lens with n=1.47 disappear in a trough of liquid. What is the refractive index of the liquid? Could the liquid be water?**

Ans. For disappearance of the glass lens, the refractive index of the liquid must be greater than the refractive index of the given glass lens i.e. if $n_1=1.47$ for glass lens then $n_2 = 1.5$ for given liquid.

Reasons and Explanation:

Part a: When the glass lens of refractive index 1.47 is placed in liquid in which the lens disappears,

it means that the refractive index of liquid is greater than the refractive index of lens. As the light from lens in given liquid suffer total internal reflection due to which the light from lens will not be transmitted out from liquid, but reflect back in the same liquid and hence the lens cannot be seen. The liquid in which the lens is lying will be oil having refractive index 1.5.

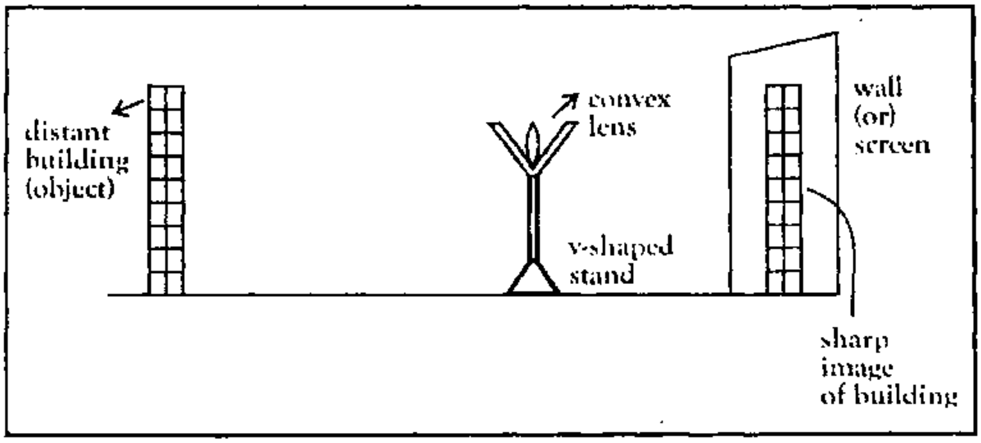
Part b: The given liquid will not be water. It is because the refractive index of water is 1.33 which is less than the refractive index of the given glass lens.

**Q5: Suppose that you were handed a lens and a ruler and told to determine the focal length of the lens, how would you proceed?**

Ans. If we are handed a lens and a ruler and told to determine the focal length of the lens, then we can use distant object method for determining the focal length of the lens.

Reasons and Explanation:

We can determine the focal length of a convex lens by distant object method. In this method the lens is kept in a v-shaped stand. The lens along v-shaped stand is placed near the wall or screen. The lens is adjusted in such a way that it produces a sharp image of the distant object like building or tree etc on the screen as shown in the figure.




When sharp image of the distant object appears on the screen, then measure the distance between lens and screen with the help of a ruler. This separation between lens and screen gives us the focal length of the convex lens.

**Q6: Can we achieve total internal reflection when light travels from optically rare medium to optically dense medium?**

Ans. We cannot achieve total internal reflection when light travels from optically rare medium to optically denser medium.

Reasons and Explanation:

There are two conditions form total internal reflection of light:

Condition-1: When the angle of incidence is greater than the critical angle i.e. $\theta_i > \theta_c$.

Condition-2: When light ray is travelling from optically denser medium to optically rare medium.

It means that when light ray is traveling from optically rare medium to optically denser medium, total internal reflection will not takes place. Thus we cannot achieve total internal reflection when light

travels from optically rare medium to optically denser medium.

**Q7: Will a near sighted person who wears corrective lenses in her glasses, be able to see clearly under water when wearing those glasses?**

Ans. No, a near sighted person who wears corrective lenses in her glasses cannot see nearly under water when wearing those glasses.

Reasons and Explanation:

The refraction of light in medium depends upon the refractive index of medium. In the medium having high index of refraction, the rays of light bend more towards the normal. The refractive index of the water is greater than the refractive index of air, so the person wearing the correct lenses in glasses cannot see clearly in water, as can be seen in air.

**Q8: When you use a simple magnifying glass, does it matter whether you hold the object to be examined closer to the lens than its focal length or further away? Explain.**

Ans. To examine an object with the help of simple magnifying glass, the object should lie within the focal length of the lens.

Reasons and Explanation:

A double convex lens may be used as a simply magnifying glass or simple microscope. A convex lens always forms a real and inverted image on the opposite side of the lens, when the object is placed away from the focal point. i.e. at a greater distance than its focal

length. For virtual, erect and magnified image, the object should be placed inside the focal point, i.e. within the focal length of the lens.

Thus, to use a simple magnifying glass, the object should lie within the focal length of the lens, so that to get an erect, enlarged and virtual image of the object.

**Q9: In blind turns on hilly roads, mirrors are used to help drivers. Are these mirrors plane mirror, concave mirrors or convex mirrors? Explain.**

Ans. Convex mirrors are used in blind turns on hilly roads which help drivers for safe and sound drive.

Reasons and Explanation:

Convex mirrors are generally used at blind corners, as they give a wider angle of vision and a larger field of view. They also form erect virtual and diminished images of objects lying away from the focal point.

On the other hand, plane mirrors form erect images of the same size reducing the field of view. And concave mirrors form erect and virtual images only when the object lie within its focal length. So, only choice is a convex mirror to be used at blind corners to help drivers for safe driving.

## Comprehensive Questions

*Given an extended response to the following questions:*

**1. What is mean by reflection of light? State and explain laws of reflection with diagrams.**

Ans. See answer of question no 1 in the text.

**2. Derive spherical mirror formula.**

Ans. See answer of question no 7 in the text.

**3. What is meant by refraction of light? What is the index of refraction? State and explain laws of refraction with diagrams.**

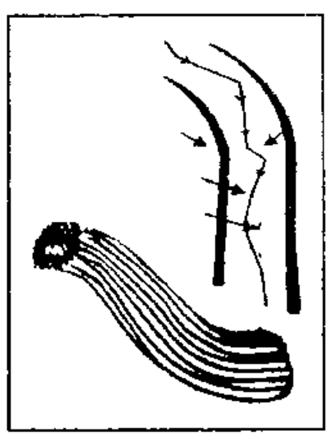
Ans. See answer of question no 11 in the text.

**4. What is total internal reflection? How we can calculate the critical angle for total reflection? What are the conditions for total internal reflection?**

Ans. See answer of question no 14 in the text.

**5. What are optical fibers? Give some applications of optical fibers.**

Ans. Optical Fibres [آپٹیکل فائبرز]



The optical fibres are thin glass rods which can trap light by total internal reflection.

Principle of Working

It works on the principle of total internal reflection of light.

Construction

It consists of flexible glass rod,

which is coated with another glass whose refractive index is less than the 1st glass rod. The ray of light enters the fibres at one end. This ray totally reflects from the sides and finally come out at the other end.

Uses of Optical Fibres

1. It is used by the doctors to see different parts of human body on the screen.
2. The optical fibres are used in telephones and other communication systems.

**6. Describe the behavior for a ray of light after passing through a prism.**

Ans. See answer of question no 13 in the text.

**7. Derive thin lens equation.**

Ans. See answer of question no 23 in the text.

**8. Describe power of lens and its resolving power. What are its units?**

Ans. See answer of question no 22 in the text.

**9. How the human eye works? How the defects in the eye like short sightedness and long sightedness be corrected by using lenses?**

Ans. See answer of question no 25, 26 in the text.

**10. What is a simple microscope? Using a ray diagram explain its working, angular magnification and magnifying power.**

Ans. See answer of question no 27 in the text.

**11· What is a compound microscope? Using ray diagram for a compound microscope, mention its magnifying power·**

Ans· See answer of question no 28 in the text·

**12· What is a telescope? Using a ray diagram explain its working, angular magnification and magnifying power·**

Ans· See answer of question no 29 in the text·

## Numerical Questions

**Q1: A 1·5cm high object is placed 20·0cm from a concave mirror with radius of curvature 30·0cm· Determine (a) the position of the image, and (b) its size, also draw the ray diagrams·**

Solution:

Given data: Height of object $= h_o = 1{\cdot}5cm$

Distance of object $= d_o = 20cm$

Radius of curvature $= R = 30cm$

Required: (a) Position of image $= d_i = ?$

(b) Size of image $= h_i = ?$

Calculation: (a) We know that

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

$$\Rightarrow \quad \frac{1}{d_i} = \frac{d_o - f}{fd_o} \Rightarrow d_i = \frac{fd_o}{d_o - f} \text{ ——— } (1)$$

As focal length "f" is also not given, so for "f" we have,

$$f = \frac{1}{2}R = \left(\frac{1}{2} \times 30\right)cm \Rightarrow f = 15cm$$

Now putting the values in equation (1), we get,

$$d_i = \left(\frac{15 \times 20}{20-15}\right)cm = \left(\frac{300}{5}\right)cm = 60cm$$

$$\Rightarrow \quad \boxed{d_i = 60cm}$$

(b) As $M = \frac{h_i}{h_o}$ —— (2)

Also $M = \frac{d_i}{d_o}$ —— (3)

Comparing equation (2) and equation (3), we get,

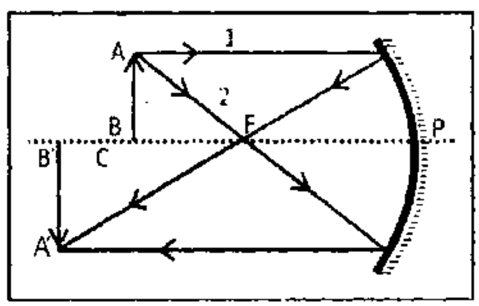
$$\frac{h_i}{h_o} = \frac{d_i}{d_o} \Rightarrow h_i = \frac{d_i h_o}{d_o} \text{ —— } (4)$$

Putting the values in equation (4), we get,

$$h_i = \left[\frac{60 \times 1\cdot5}{20}\right]cm = 4\cdot5cm$$

$$\Rightarrow \quad \boxed{h_i = 4\cdot5cm}$$

Ray Diagram:




As the distance of object is less than centre of curvature of the mirror, so the object will be situated to the right side of centre of curvature "C", as shown in the figure. Under such situation we get an image which will be real, inverted and greater in size than object, as shown in ray diagram.

Answers:

$\boxed{\text{(i) Position of image} = d_i = 60cm}$

$\boxed{\text{(ii) Size of image} = h_i = 4\cdot5cm}$

**Q2: A candle of height 8·0cm is located at a distance of 300mm from a convex mirror, its virtual image is formed behind the mirror at a distance of 3·0cm from the pole (or vertex)· Find the focal length of the mirror and height of the image formed·**

**Solution:**

**Given data:** Size of object = $h_o = 8cm$

Distance of object = $d_o = 300mm = 0{\cdot}3m = 30cm$

Distance of image = $d_i = -3cm$

**Required:** (a) Focal length of convex mirror = ?

(b) Size of image = ?

> For virtual image we take "$d_i$" negative

**Calculation:** (a) We know that,

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \text{ ——— } (1)$$

Putting the values in equation (1), we get,

$$\frac{1}{f} = \frac{1}{30} + \frac{1}{-3} = \frac{1-10}{30} = \frac{-9}{30}$$

$$\Rightarrow \quad \frac{1}{f} = \frac{-9}{30} \Rightarrow f = -\frac{-30}{9}cm \Rightarrow f = -3{\cdot}33cm$$

$$\Rightarrow \quad \boxed{f = -3{\cdot}33cm}$$

(b) We know that,

$$M = \frac{h_i}{h_o} \text{ ——— } (2)$$

Also $$M = \frac{d_i}{d_o} \text{ ——— } (3)$$

Comparing equation (2), (3), we get,

$$\frac{h_i}{h_o} = \frac{d_i}{d_o} \Rightarrow h_i = \frac{d_i h_o}{d_o} \text{ ——— } (4)$$

Putting the values in equation (4), we get,

$$h_i = \left(\frac{-3 \times 8}{30}\right)cm = \frac{-24}{30}cm$$

$\Rightarrow$ $h_i = -0.8cm$

Answers:

(i) Focal length $= f = -3.33cm$

(ii) Size of image $= h_i = -0.8cm$

**Q3: Calculate the speed of light in zircon with index of refraction n = 1.923, a material used in jewelry to replicated diamond.**

Solution:

Given data:

Speed of light in vacuum $= c = 3\times10^8 m/sec$

Refractive index $= n = 1.923$

Required: Speed of light in zircon $= v = ?$

Calculation: We know that

$$n = \frac{c}{v} \Rightarrow v = \frac{c}{n} ----(1)$$

Putting the values in equation (1), we get,

$$v = \left(\frac{3\times10^8}{1.923}\right) m/sec = 1.56\times10^8 m/sec$$

$\Rightarrow$ $v = 1.56\times10^8 m/sec$

Speed of light in zircon $= v = 1.56\times10^8 m/sec$

Answer

**Q4: A light ray strikes an air / water surface at angle of 46° with respect to the normal. The refractive index for water is 1.33. Find the angle of refraction when the direction of the ray is (a) from air to water and (b) from water to air.**

Solution:

Given data: Angle of incidence $= \theta_i = \theta_i = 46°$

Refractive index of air $= n_{air} = 1.00$

Refractive index of water $= n_w = 1.33$

Required: (a) Angle of refraction [Incase from air to water] $\theta_2 = \theta_r = ?$

(b) Angle of refraction [Incase from water to air] $\theta_2 = \theta_r = ?$

Calculation:

Part (a)

From Snell's law we have,

$$\frac{n_1}{n_2} = \frac{\sin\theta_2}{\sin\theta_1} \quad \text{------ (1)}$$

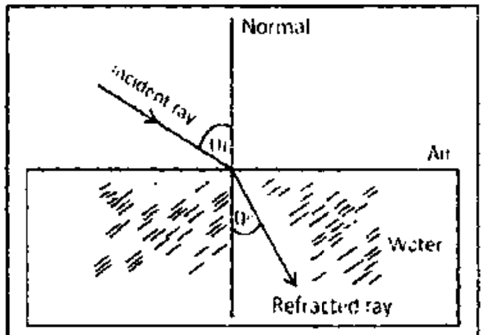



Fig (a)

From air to water, we put

$n_1 = n_{air}, n_2 = n_w, \theta_1 = \theta_i$

And $\theta_2 = \theta_r$

So equation (1) $\Rightarrow$

$$\frac{n_{air}}{n_w} = \frac{\sin\theta_r}{\sin\theta_i} \quad \text{[By cross multiplication]}$$

$$\Rightarrow \quad n_{air} \times \sin\theta_i = n_w \sin\theta_r$$

$$\Rightarrow \quad \sin\theta_r = \frac{n_{air} \times \sin\theta_i}{n_w} \quad \text{------ (2)}$$

Putting the values in equation (2), we get,

$$\sin\theta_r = \frac{1.00 \times \sin 46^\circ}{1.33} = \frac{1.00 \times 0.72}{1.33} = 0.54$$

$$\Rightarrow \quad \sin\theta_r = 0.54$$

$$\Rightarrow \quad \theta_r = \sin^{-1}(0.54) = 33^\circ$$

$\boxed{\theta_r = 33^\circ}$ Answer

Part (b): From water to air, we put

$n_1 = n_w, n_2 = n_{air}, \theta_1 = \theta_i$

And $\theta_2 = \theta_r$

So equation (1) $\Rightarrow$

$$\frac{n_w}{n_{air}} = \frac{\sin\theta_r}{\sin\theta_i}$$

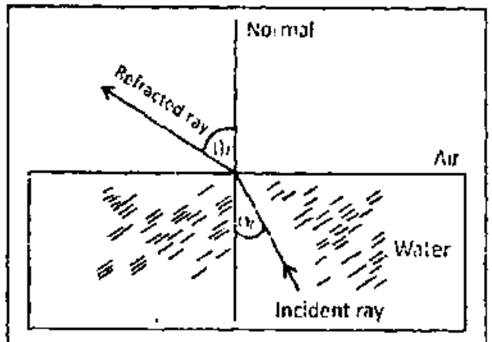


Fig (b)

[By cross multiplication]

$$\Rightarrow \quad n_w \times \sin\theta_i = n_{air} \times \sin\theta_r$$

$$\Rightarrow \quad \sin\theta_r = \frac{n_w \times \sin\theta_i}{n_{air}} \text{ ——— (3)}$$

Putting the values in equation (3), we get,

$$\sin\theta_r = \frac{1.33 \times \sin 46^\circ}{1.00}$$

$$\Rightarrow \quad \sin\theta_r = \frac{1.33 \times 0.72}{1.00} = 0.96$$

$$\Rightarrow \quad \sin\theta_r = 0.96$$

$$\Rightarrow \quad \theta_r = \sin^{-1}(0.96)$$

$$\Rightarrow \quad \theta_r = 74^\circ$$

$\boxed{\theta_r = 74^\circ}$ Answer

> Q5: An optical fiber is made from flint glass with index of refraction 1.66 and is surrounded by a cladding made of crown glass with index of refraction 1.52. What is the critical angle?

**Solution:**

**Given data:**

Refractive index $= n_1 = 1.66$

Refractive index $= n_2 = 1.52$

**Required:** Critical angle $= \theta_C = ?$

**Calculation:** We know that,

$$\sin\theta_c = \frac{n_2}{n_1} \text{------} (1)$$

Putting the values in equation (1), we get,

$$\sin\theta_c = \frac{1{\cdot}52}{1{\cdot}66} = 0{\cdot}91566265$$

$$\Rightarrow \quad \theta_c = \sin^{-1}(0{\cdot}91566265) = 66{\cdot}3^\circ$$

$\boxed{\text{Critical angle} = \theta_c = 66{\cdot}3^\circ}$ Answer

**Q6: Suppose the book page is held 7·50cm from a convex lens of focal length 10·0cm and concave lens of focal length -10cm· What magnification is produced in each case?**

Solution:

Given data: Distance of object (book) = $d_o = 7{\cdot}50cm$

(a) Focal length of convex lens = $f = 10\,cm$

(b) Focal length of concave lens = $f = -10\,cm$

Required: (a) Magnification in each case = $M = ?$

(b) Magnification incase of concave lens = $M = ?$

Calculation: First we calculate the image distance in each case, for $d_o = 7{\cdot}50cm$ and $f = 10cm$, we have

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} \Rightarrow \frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o} = \frac{d_o - f}{fd_o}$$

$$\Rightarrow \quad d_i = \frac{fd_o}{d_o - f} \text{------} (1)$$

Putting the values in equation (1), we get,

$$d_i = \frac{7{\cdot}50 \times 10}{7{\cdot}50 - 10} \Rightarrow \boxed{d_i = -30cm}$$

For concave lens, put $f = -10cm, d_o = 7{\cdot}5cm$ in equation (1), we get,

$$d_i = \left(\frac{7{\cdot}50 \times (-10)}{7{\cdot}50 - (-10)}\right) cm$$

$\Rightarrow \quad d_i = \left(\frac{-75}{17.50}\right)cm = -4.29cm$

$\Rightarrow \quad \boxed{d_i = -4.29cm}$

*Now we know that the magnification is given by,*

$$M = -\frac{d_i}{d_o} \text{ ------ } (2)$$

(a) *Now in case of convex lens, we put*
$d_i = -30cm$ & $d_o = 7.50cm$ *in equation (2), we get*

$$M = -\frac{(-30)cm}{7.5cm} = 4$$

$\boxed{M = 4}$ *Answer*

(b) *Now in case of concave lens, we put* $d_i = -4.29cm$ & $d_o = 7.50cm$ *in equation (2), we get,*

$$M = -\frac{(-4.29)cm}{7.50cm} = 0.572$$

$\boxed{M = 0.572}$ *Answer*

| |
|---|
| *Q7: Gulalai is viewing a flea using a magnifier with f = 3.0cm. If her near point is at N = 25cm then calculate the maximum magnification she can get.* |

*Solution:*

*Given data:*

*Focal length = f = 3cm*

*Near point distance = N = 25cm*

*Required:*

*Maximum magnification =* $M_m = ?$

*Calculation:*

*For maximum magnification, we have*

$$M_u = \frac{N}{f} + 1 \longrightarrow (i)$$

Putting the values in equation (i), we get,

$$M_u = \left(\frac{25}{3} + 1\right) = 8\cdot33 + 1 = 9\cdot33$$

$$\Rightarrow \quad M_u = 9\cdot33$$

$\boxed{Maximum\ magnification = M_u = 9\cdot3}$ Answer

**Q8: A telescope has a magnification of 40·0 and a length of 1230mm· What are the focal lengths of the objective and eyepiece?**

Solution:

Given data:

Magnification of telescope = $M$ = 40

Length of telescope = $L$ = 1230mm

Required:

(i) Focal length of objective = $f_o$ = ?

(ii) Focal length of eye piece = $f_e$ = ?

Calculation:

We know that the magnification of telescope is given by,

$$M = \frac{f_o}{f_e} \Rightarrow f_o = Mf_e \text{ —— } (1)$$

Also the length of telescope is given by,

$$L = f_o + f_e \text{ —— } (2)$$

Putting equation (1) in equation (2), we get,

$$L = Mf_e + f_e \Rightarrow L = (M+1)f_e$$

$$\Rightarrow \quad f_e = \frac{L}{M+1} \text{ —— } (3)$$

Putting the values of "M" and "L" in equation (3), we get

$$f_e = \left(\frac{1230}{40+1}\right)mm = \frac{1230}{41} = 30mm$$

$$\Rightarrow \quad \boxed{f_e = 30mm} \text{ ------ } (4)$$

*Putting equation (4) in equation (1), we get,*

$$f_o = 40 \times 30mm$$

$$\boxed{f_o = 1200m}$$

***Answers:***

$$\boxed{\text{(i) Focal length of objective} = f_o = 1200mm}$$

$$\boxed{\text{(ii) Focal length of eye piece} = f_e = 30mm}$$

OOO

- موت کو یاد رکھنا نفس کی تمام بیماریوں کی دوا ہے۔
- واضح اور روشن ترین راستہ حق و صداقت کا ہے۔
- دشمن کے حسنِ سلوک پر بھروسہ نہ کرو کیونکہ پانی کو آگ سے کتنا ہی گرم کیا جائے پھر بھی وہ اس کے بجھانے کو کافی ہے۔
- آدمی کی عقل اس کے کلام کی خوبی سے اور شرافت اس کے افعال کی عمدگی سے ظاہر ہوتی ہے۔
- جس نے باطل کی تائید کی گویا اس نے حق پر ظلم کیا۔
- آزادی کی حفاظت نہ کرنے والا غلامی میں گرفتار ہو جاتا ہے۔
- قناعت سب سے بڑی دولت ہے۔
- ایمانداری سب سے بہترین حکمتِ عملی ہے۔
- دنیا کی سب سے بڑی خیانت قوم کے ساتھ غداری ہے۔

CHAPTER 13

# ELECTROSTATICS

**Q1: What is electrostatics? Define charge. Explain the nature, existence and transfer of charge from one body to another body.**

برقی سکونی سے کیا مراد ہے؟ چارج کی تعریف کریں۔ برقی چارج کی نوعیت، موجودگی اور ایک دوسرے سے
جسم کو منتقلی پر بحث کریں۔

Ans. Electrostatics: (BISE Kohat, Malakand, Bannu, Peshawar 2019)

"The branch of physics in which we study the charges at rest is known as electrostatic."

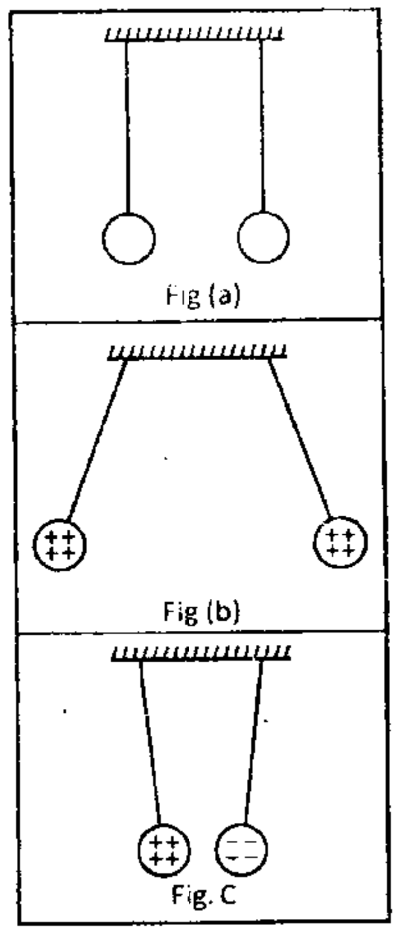


Fig (a) Fig (b) Fig. C

Charge:

It is the property of a substance due to which it can attract or repel another substance.

Nature, Existence and Transfer of Charge:

The charge is electric in nature. It may be positive or negative. The same charges repel each other, while the opposite charges attract each other. Due to presence of

charges, all bodies in the universe can be charged. The transfer of charge can be explained with the help of following experiment.

**Experiment:**

Consider two small pith balls which are suspended by means of threads as shown in the figure (a).

In the beginning, the two balls remains at their mean position because they are neutral. Now if we touch each ball with positively charged glass rod and then leave them free, they will repel each other as shown in figure (b). Infact, the two balls acquire positive charge from the glass rod and thus repel each other.

Similarly, if we touch one ball with positively charged rod and the other with negatively charged rod and then leave them free, then they will attract each other, as shown in figure (c).

**Conclusion [نتیجہ]**

The above experiment shows that the charges can exists in the universe and they can be transfer from one body to another body.

**Q2: Discuss the electric nature of matter. (OR) Discuss the structure of atom.**

مادے کی برقی نوعیت پر بحث کریں۔(یا) ایٹم کی ساخت بیان کریں۔

Ans. In general, the matter is electrically neutral. The amount of positive charges and negative are equal in neutral matter. The electric nature of matter can be explained on the basis of structure of atom.

*Structure of Atom [ایٹم کی ساخت]*

*The smallest particle of matter is known as atom. The nucleus of the atom consists of protons and neutrons. The protons are positively charged particles while the neutrons are neutral particles. The mass of proton is $1.67\times10^{-27}$ kg, while the mass of neutron is slightly less than of proton. The charge on proton is $1.6\times10^{19}$ C.*

*The electrons are third particles which are revolving around the nucleus in circular orbits. The mass of electron is $9.1\times10^{-31}$ kg and the charge on electron is $1.6\times10^{19}$ coulomb. Under normal conditions, the number of electrons and number of protons are equal. Thus the atom is electrically neutral under normal conditions.*

> *Q3: Distinguish between electrical conductors and insulators. Explain materials on the basis of atomic electrical theory of matter.*
> موصل اور غیر موصل اشیاء میں کیا فرق ہے؟ مادے کے برقی نظریے کے تحت اشیاء کی برقی ایصالیت پر بحث کریں۔

*Ans. (1) Conductors [موصل]: (BISE Bannu 2019)*

*"Those substance through which electric charge can flow easily, are known as conductors."*

*Explanation [وضاحت]*

*The number of electrons in the outermost shell of an atom is known as valence electrons. In conductor, the valence electrons are loosely bounded to their parent atom. These electrons can freely move within certain solids. Such electrons are known as free electrons. These electrons make the flow of current through the conductors.*

*Examples:* Copper, iron, aluminum etc are the examples of conductors.

### (2) Insulators [حاجز، غیر موصل]

"Those substances through which electric charge cannot flow easily are known as insulators."

*Explanation [وضاحت]*

In insulators, the valence electrons are tightly bounded to their parent atoms. So they cannot move freely through the insulators. In case of charged insulators, the charge is locally confined [محدود] and cannot spread over the surface of insulator. So in the use of electricity, the conductors are covered with insulators for safety purposes.

*Examples [مثالیں]:* The examples of insulators are rubber, plastic, glass and dry wood etc.

### Electrical conductivity of materials on the basis of atomic electric theory of matter:

A substance is neither a perfect insulator nor a perfect conductor. The conductivity of a substance can be determines by the number of free electrons in that substance. It can be explain with the help of following examples:

1. The air is an insulating medium but under the influence of electric forces, the air behaves as conductor temporarily.
2. The pure water is an insulator. But if we introduce small amount of salt, then the water becomes a conductor.
3. The earth is conductor. It is a huge reservoir for receiving or supplying electrons to other bodies.

4. If we want to discharge a charged body, then this body is connected to earth by means of a conducting wire.

**Q4: A material is neither a perfect conductor nor perfect insulator. Explain this.**
ہر جسم نہ تو مکمل طور پر موصل ہوتا ہے اور نہ مکمل طور پر غیر موصل، اس بیان کی تشریح کریں۔

Ans. A material is neither a perfect conductor nor perfect insulator, because under certain cases, an insulator may behave like a conductor and the conductor may behave like an insulator. For example, air is an insulator. But due to strong electric forces, it may becomes a conductor temporarily. Similarly, the air between ground and charged clouds becomes a conductor and allows the flow of current.

**Q5: What do you mean by electrostatic induction? How does a charged body attract small pieces towards itself?**
سکونی برقی آمالہ سے کیا مراد ہے؟ چارج شدہ اجسام ہلکی پھلکی تعدیلی اشیاء کو اپنی طرف کیوں کھینچتے ہیں؟ وضاحت کریں۔

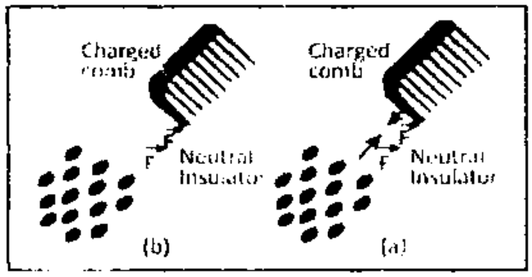
Ans. Electrostatic Induction [سکونی برقی آمالہ]
(BISE Mardan 2019)
"The phenomenon in which a charged body changes the charge distribution of nearby neutral body, is known as electrostatic induction."

Explanation [وضاحت]
When a charged body is brought nearer towards a neutral body, then the negative and positive charges of the neutral body rearranges themselves on the

surface as well as in the interior of the body. This effect is known as electrostatic induction. The neutral body can regain its original state by removing the charged body from it. Using this method, we can charge insulators as well as conductors.

1) Charging an Insulator by Induction [غیر موصل جسم کو برقی آمالے سے بار کرنا]

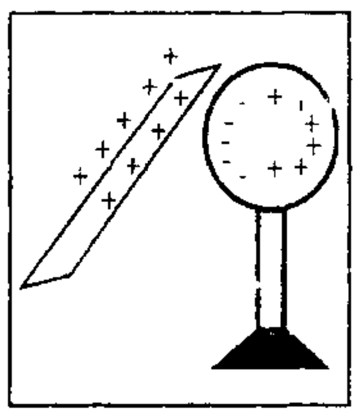
When a negatively charged comb is brought near to a neutral insulator, then the insulator becomes polarized i.e.




the atoms of insulator adopt themselves into plus and minus poles of charges. The plus charges of insulator remain closer to the negatively charged comb. While the negative charges of the insulator remains away from the negatively charged comb. In this way the comb attracts the insulator towards itself.

2) Charging a Conductor by Induction [موصل اجسام کو برقی آمالے سے بار کرنا]

Consider a metallic sphere which is placed on an insulating wooden stand as shown in the figure. If we bring a positively charged rod near the sphere, then the charge distribution of the sphere changes and the free electrons of the sphere will arrange themselves closer to the rod.

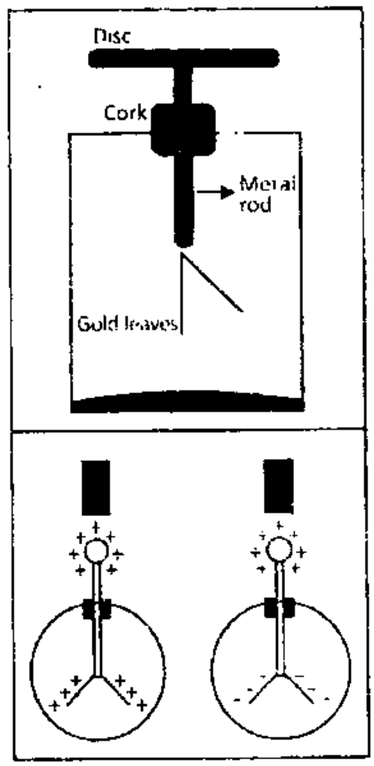


In this way, forces of attraction take place be-

tween rod and the sphere. Such distribution of charges inside the sphere due to positive rod is known as charging a conductor by induction.

**Q6: What is the function of electroscope? How can we use electroscope to find the presence and nature of charge on a body?**
الیکٹروسکوپ کا مقصد کیا ہے؟ اس کے ذریعے ہم چارج کی موجودگی اور نوعیت کیسے معلوم کرتے ہیں؟

Ans. Leaf Electroscope [برق نما]




It is a device which is used for testing the nature of electric charges.

Construction [ساخت]

A simple electroscope consists of a metal rod. One end of this rod is attached to a disc while the other end is attached to gold leaves as shown in the figure. The rod is fitted in a metal case with glass windows.

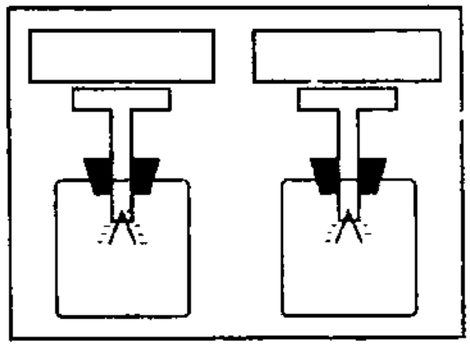
Charging an Electroscope:

When a positively charged body is brought in contact with the knob of an electroscope, then the electrons of the rod and gold leaves transfers to the body and thus the leaves of electroscope becomes positively charged.

Similarly, when negatively charged body is brought in contact with electroscope, then the leaves becomes negatively charged.

***Testing for Positive (or) Negative Charge on a body:***

Let the electroscope is charged positively. Now if we bring a body near the knob of electroscope and the gold leaves diverges, then the body will be positively charged. And if the leaves collapse then the body will be negatively charged.



**Q7: State and explain coulomb's law. Define the unit of charge (i.e. coulomb)**

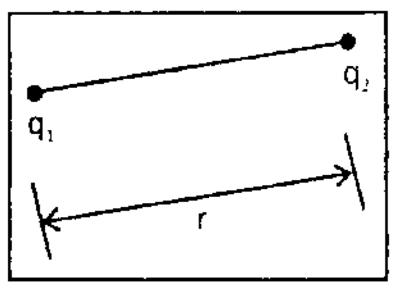
کولمب کا قانون بیان کریں اور اس کی وضاحت کریں۔ چارج کی اکائی کی تعریف کریں۔

Ans. **Statement [بیان]:** (BISE Peshawar, Kohat 2019)

This law states that, "the force of attraction or repulsion between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them."

**Explanation [وضاحت]**

Consider two point charges "$q_1$" and "$q_2$" placed in air at a distance "r" from each other, as shown in the figure.




Now according to coulomb's law, we have,

$$F \propto q_1 q_2 \text{ ---- (1)}$$

And $F \propto \frac{1}{r^2}$ ---- (2)

Combining relation (1) and (2), we get,

$$F \propto \frac{q_1 q_2}{r^2} \Rightarrow F = constt \cdot \frac{q_1 q_2}{r^2}$$

$$\Rightarrow \quad F = \frac{kq_1q_2}{r^2} \text{ ——— } (3)$$

In equation (3) "K" is constant and is known as coulomb's constant.

For air or free space, its value is given by,

$$K = \frac{1}{4\pi\epsilon_o} \text{ (or) } K = 9\times 10^9 Nm^2/c^2$$

So equation (iii) $\Rightarrow$ $\boxed{F = \frac{1}{4\pi\epsilon_o}\frac{q_1q_2}{r^2}}$ ——— (4)

In equation (4), "$\epsilon_o$" is known as permittivity of free space or air.

<u>Coulomb's force in case of dielectric medium:</u>

If the medium between the two charges is other than air i.e. dielectric, then equation (4) can be written as,

$$\boxed{F' = \frac{1}{4\pi\epsilon}\frac{q_1q_2}{r^2}} \text{ ——— } (5)$$

In equation (5), "$\epsilon$" is known as permittivity of dielectric medium.

<u>Unit of Charge [چارج کی اکائی]</u>

The S.I unit of charge is coulomb.

<u>Definition of Coulomb</u>

"One coulomb is the amount of charge which repel an equal and similar charge with a force of $9\times10^9 N$. when placed in air at a distance of 1m from each other."

$$\begin{bmatrix} 1 \text{ microcoulomb } (\mu C) = 10^{-6} C \\ 1 \text{ micro microcoulomb} = (\mu\mu C) = 10^{-12} C \end{bmatrix}$$

**Q8: Compare coulomb's law with Newton's law of gravitation.** کولمب کے قانون اور نیوٹن کے قانون تجاذب کا موازنہ کریں۔

Ans. (BISE Kohat, Malakand 2019)

| Coulomb's Force | Gravitational Force |
|---|---|
| ▪ Coulomb's force exists between point charges. | ▪ Gravitational force exists between masses. |
| ▪ Coulomb's force is attractive as well as repulsive in nature. | ▪ Gravitational force is only attractive in nature. |
| ▪ Coulomb's force varies inversely with distance i.e. $F_e \propto \frac{1}{r^2}$ | ▪ Gravitational force also varies inversely with distance i.e. $F_g \propto \frac{1}{r^2}$ |
| ▪ Coulomb's force or electrostatic force is fundamental force. | ▪ Gravitational force is also fundamental force. |
| ▪ Mathematical form of coulomb's force is, $F_e = \frac{kq_1q_2}{r^2}$ | ▪ Mathematical form of gravitational force is, $F_g = \frac{Gm_1m_2}{r^2}$ |

**Q9: What do you mean by electric field? How it is represented by lines of force? Provide figures for illustrations.**

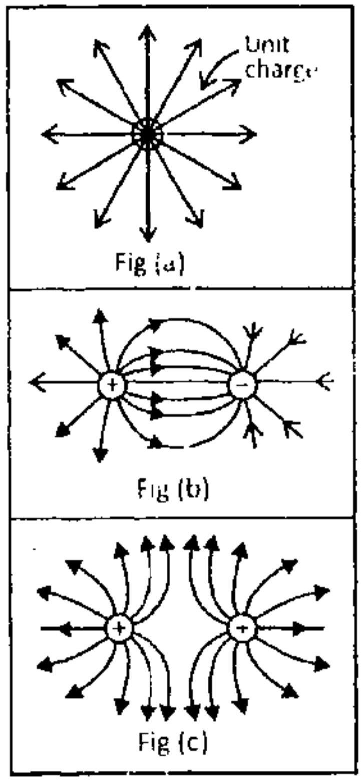
برقی فیلڈ سے کیا مراد ہے؟ اس کو خطوط قوت سے ظاہر کیا جاتا ہے، اشکال سے وضاحت کریں۔

Ans. Electric Field [برقی فیلڈ]

Definition: "The region around a charge in which the effect of that charge can be felt, is known as electric field."

*Explanation [وضاحت]:*

*An electric charge can exert coulomb's force on another charge in its electric field. The path along which a tiny positive charge moves in an electric field is known as electric field lines. Now the number of electric lines of forces passing through a certain area is known as electric lines of forces. The electric lines of forces represent the electric field in the vicinity of charged bodies. For example:*




1. *Figure (a) represents the lines of force diagram for point charges.*
2. *Figure (b) represents the lines of force diagram for opposite charges.*
3. *Figure (c) represents the lines of force diagram for identical charges.*

> *Q10: Define electric field intensity. Explain its magnitude and direction. Provide figure for illustration.*
> برقی فیلڈ کی شدت کی تعریف کریں۔ اس کی مقدار اور سمت پر بحث کریں۔ شکل سے وضاحت کریں۔

*Ans. Electric Field Intensity [برقی فیلڈ کی شدت]*

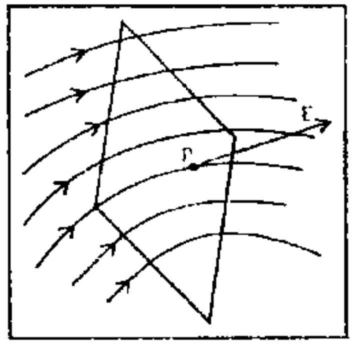
*"The electric force experienced by a unit test charge placed at a certain point in electric field, is known as electric field intensity."*

*Explanation [وضاحت]*

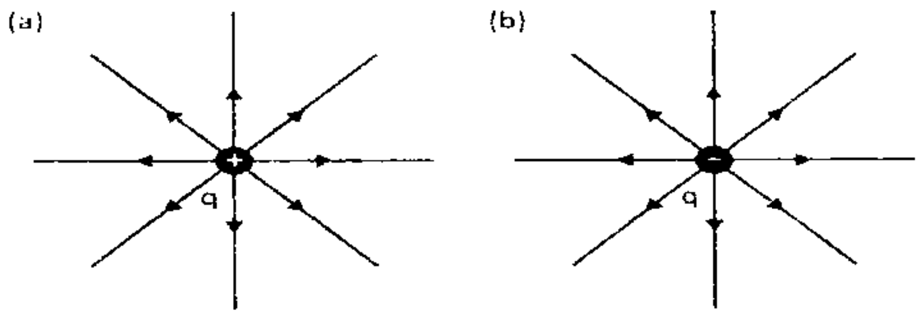
*Let "F" represents the magnitude of electrostatic*

*force on a unit positive charge "q", then the magnitude of electric field intensity "E" is given by,*

$$\boxed{E = \frac{F}{q}} \quad \text{——(1)}$$




**Electric field lines for point charges**




(a) For a positive point charge, the lines radiate radially outwards

(b) For a negative point charge, the lines converge radially inwards

*The electric field intensity is a vector quantity. Its direction is the same as that of the force "F" on charge "q". It helps us to visualize the electric field. The electric field lines give us the direction and strength of the field at various places. The direction of the lines is radially outwards for a positive charge and radially inwards for a negative charge, as shown in the figure.*

***Unit of Electric Field Intensity:***

*The SI unit of electric field intensity is "N/C".*

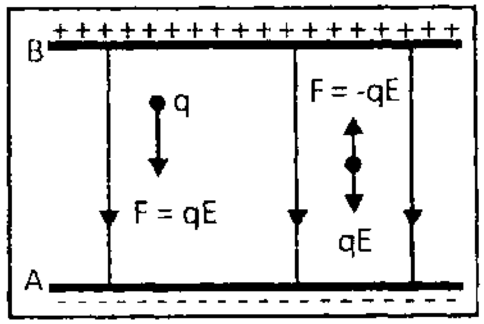
| |
|---|
| ***Q11: Define and explain electric potential, and its unit.*** <br> برقی پوٹینشل کے فرق کی تعریف کریں اور وضاحت کریں۔ اس کی اکائی کی بھی تعریف کریں۔ |

*Ans. Electric Potential [برقی پوٹینشل]*

*Definition: "The workdone in moving a unit positive*

*charge from one point to another against electric field is known as electric potential."*

*Explanation [وضاحت]*




*Consider a unit positive charge in a uniform electric field between two plates "A" and "B", as shown in the figure. If the intensity of electric field is "E", the electric force on the charge will be "qE".*

*Now if the charge moves from "B" towards "A" due to electric force, then work must be done by the electric field on the charge. This work appears as K.E in the charge. Now if we apply an equal force opposite to the electric force, then the charge will not acquire further K.E and will move in state of equilibrium. This work on the charge from "A" towards "B" is equal to the change in P.E of the charge (or) equal to potential difference "$\Delta V$". So we have,*

$$\Delta V = \frac{work}{charge} \Rightarrow \Delta V = \frac{w}{q} \text{ —— } (1)$$

*Here* $\Delta V = V_B - V_A$

*So equation (1)* $\Rightarrow$

$$\boxed{V_B - V_A = \frac{w}{q}} \text{ —— } (2)$$

*__Unit of Electric Potential__ [برقی پوٹینشل کی اکائی]*

*From equation (1), we have,*

$$\Delta V = \frac{w}{q} = \frac{1\,Joule}{1\,coulomb}$$

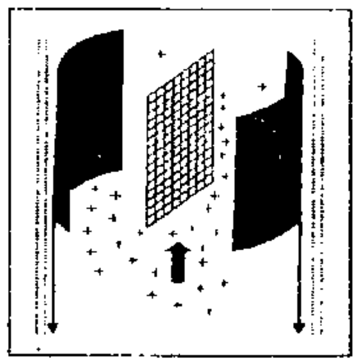
$$\Rightarrow \quad \Delta V = \frac{1J}{1C} = 1volt$$

So the unit of electric potential is "volt" which is defined as "the potential difference [P·D] is said to be one volt if one joule work is done on a unit positive charge to move it from one point to another point in an electric field·"

**Q12: Give some practical applications of electrostatics?** برقیات سکونی کے عملی اطلاقات بیان کریں۔

Ans· (1) Dust Extraction [گرد کی صفائی]

The electrostatic can be used for cleaning air from dust particles· For this purpose a wire gauze is fixed between two metallic plates· These plates are earthed and the wire gauze is charged positively· This gauze produces negative charges on the inner faces of the plates· So a strong electric field is setup between gauze and plates· This electric field ionizes the gases and thus the dust particles become separate from air and other gases·



2) Electro-Painting

The electrostatics can be used in applying paints on the surfaces of automobiles, refrigerators etc·



For this purpose the body is earth electrically· Now when the particles of paint emerge out of the nozzle of the spray machine,

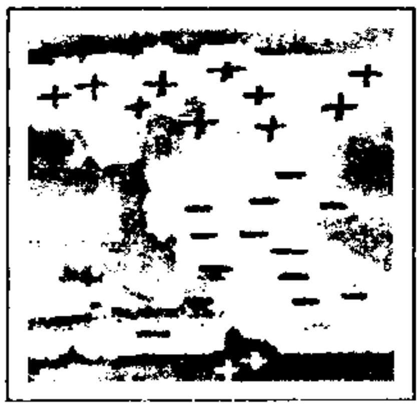
they become positively charged due to friction· So when these particles of paints fall on the surface of the body, they become a firm coat due to strong force of attraction·

**Q13: How lightning occurs? How we can safeguard ourselves from lightning hazard?**

آسمانی بجلی کیسے واقع ہوتی ہے؟ اس سے بچاؤ کیسے ممکن ہے؟ (یا) برقی سکونی کے نقصانات بیان کریں۔

Ans· Hazards of Electrostatic [برقی سکونی کے نقصانات]

Lightning [آسمانی بجلی] is a huge hazard of electrostatic which arises due to separation of charges within a cloud· Clouds are composed of millions of ice particles and water droplets· These particles collide with other condensing moisture as it rises, and when they do so, electrons are knockout· These electrons build up at the bottom of a cloud and make it negatively charged as shown in the figure·



The rising moisture molecules loss the electrons and thus positive charge is gathered at the top of cloud·

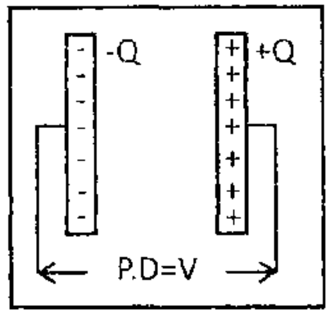
In this way, the charge separation occurs due to which an electronic field is set up between the separated charges· The electric field becomes stronger and stronger due to collision among particles· When the charges become powerful sufficiently, then the cloud's electricity is discharged towards earth's surface, which results in lightning which causes destruction on a large scale·

**Q14: What is electric capacitor? Define and explain capacitance. Define the unit of capacitance.**
کپیسٹر کیا ہوتا ہے؟ برقی گنجائش کی تعریف اور وضاحت کریں۔ اس کی اکائی کیا ہے؟

**Ans. Electric Capacitor [برقی کپیسٹر]**

**Definition:** "It is a device which is used for strong electrical charge."

**Explanation [وضاحت]**




The simplest type of capacitor consists of two metal plates of the same size and shape. One plate is positively charged and the other is negatively charged. The space between the plates is filled with an insulator, such as air, mica, paper etc.

**Capacitance of a Capacitor [کپیسٹر کی گنجائش]**

**Definition:** "The capacity of a capacitor to store charge is known as its capacitance."

**Explanation [وضاحت]**

If "Q" is the amount of charge produced on a capacitor by applying a P.D "V" between its plates, then

$$Q \propto V \Rightarrow Q = \text{Constant} \cdot V$$

$$\Rightarrow \boxed{Q = CV} \text{———} (1)$$

In equation (1), "C" is constant and is known as capacitance of the capacitor.

**Unit of Capacitance [کپیسٹر کی اکائی]**

From equation (1), we have,

$$C = \frac{Q}{V} = \frac{1\,Coulomb}{1\,Volt} \Rightarrow C = \frac{1\,Coulomb}{1\,Volt}$$

$\Rightarrow \quad C = 1 \text{ Farad}$

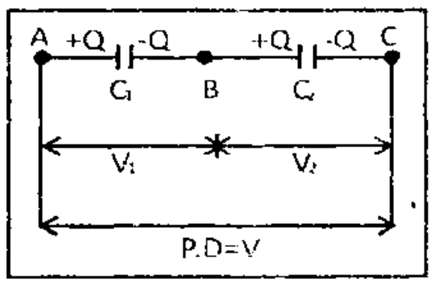
So the unit of capacitance is Farad which is defined as, "The capacitance of a capacitor is said to be one Farad, if one coulomb charge is produce on the capacitor by applying a potential difference of one volt between its plates."

**Q15: Discuss the series combination of capacitors. Describe the characteristic features of this combination.** کپیسٹرز کی سلسلہ وار جوڑ کی وضاحت کریں۔ اس جوڑ کے خصوصیات بیان کریں۔

Ans. Series Combination of Capacitors [کپیسٹرز کی سلسلہ وار جوڑ]

In case of series combination, the charge remains undivided while the P.D is divided into parts.

The series combination of two capacitors is shown in the figure. From this figure, we see that the P.D "V" is divided into two parts i.e. "$V_1$" and "$V_2$".




So $\quad V = V_1 + V_2$ ——— (1)

Now we know that,

$$Q = CV \Rightarrow V = \frac{Q}{C}$$

So $\quad V_1 = \frac{Q}{C_1}$ and $V_2 = \frac{Q}{C_2}$

[Charge "Q" remain undivided)

So equation (1) becomes,

$$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2}$$

$$\Rightarrow \quad \frac{\not{Q}}{C} = \not{Q}\left[\frac{1}{C_1} + \frac{1}{C_2}\right] \quad \text{[Taking "Q" as common]}$$

$$\Rightarrow \quad \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \text{ ——— (2)}$$

$$\Rightarrow \quad \frac{1}{C} = \frac{(C_2 + C_1)}{C_1 C_2} \Rightarrow \boxed{C = \frac{C_1 C_2}{C_1 + C_2}} \text{——} (3)$$

Equation (3) represents the equivalent capacitance due to combination of two capacitors in series. Now if "N" numbers of capacitors are connected in series, then the equivalent capacitance due to N-number of capacitors is given by,

$$\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots\cdots\cdots + \frac{1}{C_n}}$$

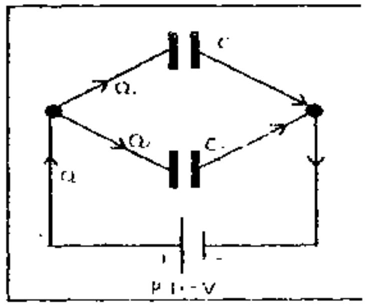
Characteristics Features of Series Combination:

1. Series combination provides only one path for the flow of charges.
2. Same charge is produced on each capacitor in series combination.
3. The sum of individual voltage is equal to the voltage of the source.
4. The reciprocal of equivalent capacitance is equal to the sum of reciprocal of individual capacitance i.e. $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots\cdots\cdots\cdots\cdots + \frac{1}{C_n}$
5. The value of equivalent capacitance is always less than the capacitance of any individual capacitor connected in series.
6. The relation between charge, capacitance and voltage is given by, $Q = CV$

**Q16: Discuss the parallel combination of capacitors. Describe the characteristics features of parallel combination.** کپیسٹرز کی متوازی جوڑ کی وضاحت کریں۔ اور اس جوڑ کے نمایاں خصوصیات لکھیں۔

Ans. Parallel Combination [متوازی جوڑ]: In case of parallel

combination, the P·D remains undivided while the charge is divided into parts, as shown in the figure·



Now for the given figure, we have,

$Q = Q_1 + Q_2$ ——— (1)

We know that,

$Q = CV \Rightarrow Q_1 = C_1V, Q_2 = C_2V$

So equation (i) $\Rightarrow CV = C_1V + C_2V$

[In parallel, $V_1 = V_2 = V$]

$\Rightarrow \quad CV = V[C_1 + C_2] \Rightarrow \boxed{C_{eq} = C_1 + C_2}$ —— (2)

Equation (2) represents the equivalent capacitance due to combination of two capacitors connected in parallel· Now if there are N-number of capacitors, then equation (2) can be written as,

$\boxed{C_{eq} = C_1 + C_2 + C_3 + \cdots\cdots\cdots + C_n}$ ——— (3)

Equation (iii) represents the equivalent capacitance due to combination of N-number of capacitors·

**Characteristics Features of Parallel Combination of Capacitors:**

1· There are various paths for the flow of charges·
2· The amount of charge "Q" is equal to the sum of the charges "$Q_1$", "$Q_2$" etc flowing through path "1", "2" etc in the circuit· i·e·,
$Q = Q_1 + Q_2 + \cdots\cdots$ etc
3· The voltage remains undivided·
4· The equivalent capacitance is equal to the sum of individual capacitance i·e·,
$C_{eq} = C_1 + C_2 + C_3 + \cdots\cdots$ etc
5· The magnitude of equivalent capacitance is

greater than the magnitude of any individual capacitance connected in circuit.

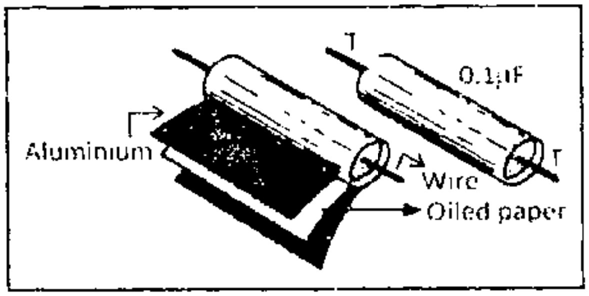
6. The relation between charge "Q", voltage "V" and capacitance "C" is given by,

$$Q = CV$$

**Q17: Discuss the various types of capacitors.**
**کیپسٹرز کی مختلف اقسام بیان کریں۔**

Ans. (1) Fixed Capacitors

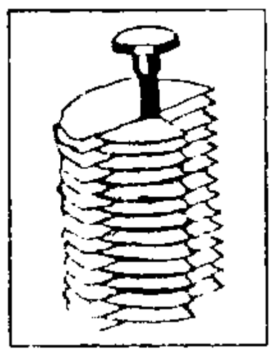
These are those capacitors whose parts are fixed by design. The capacitance of these capacitor are constant and cannot be varied.




Examples: Paper capacitor, mica capacitor etc are the examples of fixed capacitors.

2) Variable Capacitors

These are those capacitors which consist of both fixed and movable parts. The capacitance of these capacitor are not constant and can be increased (or) decreased.



These capacitors are generally used for tuning in radio sets.

## Solution of Examples, Assignments

*Example 1: The two protons and two neutrons in the nucleus of the helium atom are held together by the strong force, which is required to overcome the electrostatic repulsion between the protons. The charge of each proton is $q_p = +1.6 \times 10^{-19}C$. A distance of approximately $r = 2 \times 10^{-15}m$ separates the two protons. Calculate the magnitude of the electrostatic force between the protons.*

**Solution:**

**Given data:** Charge on proton $= q_p = +1.6 \times 10^{-19} C$

Distance $= r = 2 \times 10^{-15} m$

Coulomb constant $= k = 9 \times 10^9 Nm^2 / C^2$

**Required:** Force $= F_E = ?$

**Calculation:** Using coulomb's law, we can find the force, i.e.

$$F_e = \frac{kq_1q_2}{r^2} = \frac{kq_p \cdot q_p}{r^2} \Rightarrow F_e = \frac{kq_p \cdot q_p}{r^2} \text{ ——(1)}$$

Putting the values in equation (1), we get

$$\Rightarrow \quad F_e = \left[\frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{(2 \times 10^{-15})^2}\right] N$$

$$\Rightarrow \quad F_e = 57.6N \Rightarrow \boxed{F_e = 58N}$$

$\boxed{F_e = 58N}$ Ans.

*Assignment 1: A small metal sphere with a charge of $-2.10 \times 10^{-6}C$ is brought near an identical sphere with a positive charge of $1.50 \times 10^{-6}C$ so that the distance between the centres of the two spheres is 3.30cm. Calculate the magnitude of the force*

that each charge exerts on the other.

Solution:

Given data: Charge on one sphere $= q_1 = 2.10 \times 10^{-6} C$

Charge on other sphere $= q_2 = 1.5 \times 10^{-6} C$

Distance of separation $= r = 3.30cm = 0.033m$

Required: Magnitude of force $= F_e = ?$

Calculation: We know that,

$$F_e = \frac{kq_1q_2}{r^2}$$

$$\Rightarrow \quad F_e = \left[\frac{9\times10^9 \times 2.1\times10^{-6} \times 1.5\times10^{-6}}{(0.033)^2}\right]N$$

$$\Rightarrow \quad F_e = 26033.0 \times 10^{-3} N$$

$$\Rightarrow \quad F_e = 26.033N$$

$$\boxed{F_e = 26.0N} \quad Ans.$$

Example 2: A positive test charge of μC is placed in an electric field. Force on it is 0.600N. What is the magnitude of electric field at the location of test charge.

Solution:

Given data: Test charge $= q_o = 30\mu C = 30\times10^{-6} C$

Force $= F_e = 0.600N$

Required: Electric field intensity $= E = ?$

Calculation: We know that,

$$E = \frac{F}{q_o} = \left(\frac{0.600}{30\times10^{-6}}\right)\frac{N}{C} = 0.02\times10^6\frac{N}{C} = 2.0\times10^4\frac{N}{C}$$

$$\Rightarrow \quad \boxed{E = 2.0\times10^4 N/C}$$

Assignment 2: If a charge of $4\mu C$ is placed in a uniform field of strength $2NC^{-1}$, what force will it experience?

**Solution:**

**Given data:** Charge $= q_o = 4\mu C = 4 \times 10^{-6} C$

Electric field intensity $= E = 2NC^{-1}$  $[10^{-6} = micro = \mu]$

**Required:** Magnitude of force $= F_e = ?$

**Calculation:** We know that,

$$E = \frac{F}{q} \Rightarrow F = qE \text{ —— } (1)$$

Putting the values in equation (1), we get

$$E = \frac{F}{q} \Rightarrow F = qE = [4 \times 10^{-6} \times 2] N$$

$$\Rightarrow F = 8 \times 10^{-6} N = 8\mu N$$

$$\boxed{F = 8\mu N} \text{ Ans.}$$

> Example 3: How much work must be done to increase the potential of a charge $2.5 \times 10^{-7}C$ by 100V.

**Solution:**

**Given data:** Charge $= q = 2.5 \times 10^{-7} C$

Potential $= V = 100V$

**Required:** Workdone $= w = ?$

**Calculation:** We know that,

$$V = \frac{w}{q} \Rightarrow w = qV \text{ —— } (1)$$

Putting the values in equation (1), we get

$$w = (2.5 \times 10^{-7} \times 100) J = 2.5 \times 10^{-5} J$$

$$\boxed{w = 2.5 \times 10^{-5} J} \text{ Ans.}$$

⊛ اللہ کے خوف سے عمر میں اضافہ ہوتا ہے، شر پسندوں کی عمر کم ہو جاتی ہے۔
⊛ جب انسان کی روش اللہ کی مرضی کے مطابق ہوتی ہے تو وہ دشمنوں کو بھی دوست بنالیتا ہے۔

**Assignment 3: How much work is done in moving a charge of 3C from a point at 118V to a point at 138V in an electric field?**

**Solution:**

**Given data:** Charge $= q = 3C$

Potential at one point $= V_1 = 118V$

Potential at another point $= V_2 = 138V$

Potential difference $= \Delta V = V_2 - V_1 = (138 - 118)V$

$\Rightarrow \quad \Delta V = 20V$

**Required:** Workdone $= \Delta w = ?$

**Calculation:** We know that,

$$\Delta V = \frac{\Delta w}{q} \Rightarrow \Delta w = q\Delta V \text{ ——— } (1)$$

Putting the values in equation (1), we get

$$\Delta w = q\Delta V = 3 \times 20J = 60J$$

$\boxed{\Delta w = 60J}$ Ans.

**Example 4: A typical capacitor in an MP3 player has $C = 0.10\mu F$. If a charge $5.0\mu C$ is placed on the plates, what is the voltage across the capacitor?**

**Solution:**

**Given data:** Charge $= Q = 5\mu C = 5 \times 10^{-6} C$

Capacitance $= C = 0.10\mu F = 0.10 \times 10^{-6} F$ $\boxed{\text{Micro} = 10^{-6}}$

**Required:** Voltage = "V" = ?

**Calculation:** We know that,

$$Q = CV \Rightarrow V = \frac{Q}{C} \text{ ——— } (1)$$

Putting the values in equation (1), we get

$$V = \frac{Q}{C} = \frac{5 \times 10^{-6}}{0.10 \times 10^{-6}} = 50V$$

$\boxed{V = 50V}$ Ans.

**Assignment 4: The potential difference across the plates of the capacitor is 500V. The charge on each plate is 0.02C. What is the capacitance of the capacitor?**

Solution:

Given data: Potential difference $= V = 500V$

Charge $= Q = 0.02C$

Required: Capacitance $= C = ?$

Calculation: We know that,

$$Q = CV \Rightarrow C = \frac{Q}{V} \text{———} (1)$$

Putting the values in equation (1), we get

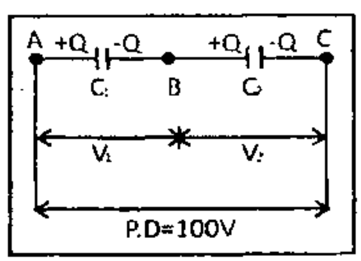
$$C = \frac{Q}{V} = \left[\frac{0.02}{500}\right] Farad \qquad [10^{-6} = micro]$$

$$\Rightarrow \quad C = 4.0 \times 10^{-5} = 40.0 \times 10^{-6} F = 40\mu F$$

$\boxed{F = 40\mu F}$ Ans.

**Example 5: Two capacitors of $5\mu F$ and $10\mu F$ are connected in series with the external source of voltage is 100V. Calculate the total capacitance and the potential drop across each capacitor.**

Solution:




Given data:

Capacitor $= C_1 = 5\mu F = 5 \times 10^{-6} F$

Capacitor $= C_2 = 10\mu F = 10 \times 10^{-6} F$

Voltage $= V = 100V$

Required: Equivalent capacitance $= C_{eq} = ?$

Potential drops $V_1$ and $V_2 = ?$

Calculation: For series combination the equivalent ca-

pacitance is given by,

$$\frac{1}{C_{eq}}=\frac{1}{C_1}+\frac{1}{C_2} \Rightarrow \frac{1}{C_{eq}}=\frac{C_2+C_1}{C_1C_2}$$

$$\Rightarrow \quad C_{eq}=\frac{C_1C_2}{C_2+C_1} —— (1)$$

Putting the values in equation (1), we get

$$C_{eq}=\left(\frac{5\times10^{-6}\times10\times10^{-6}}{5\times10^{-6}+10\times10^{-6}}\right)F=\frac{50\times10^{-6-6}}{(5+10)10^{-6}}$$

$$(OR)\quad C_{eq}=\left(\frac{50\times10^{-12}}{15\times10^{-6}}\right)F$$

$$C_{eq}=3\cdot33\times10^{-6}F=3\cdot33\mu F$$

$$\boxed{C_{eq}=3\cdot33\mu F}\quad Ans\cdot$$

In series combination, the charge remains the same, so we have,

$$Q_1=Q_2=Q$$

The charge on each capacitor is given by,

$$Q=C_{eq}V —— (2)$$

Putting the values in equation (2), we get,

$$Q=3\cdot33\times10^{-6}F\times100V=3\cdot33\times10^{-4}C$$

$$\Rightarrow \quad Q=3\cdot33\times10^{-4}C$$

(i) The potential drop across "$C_1$" is given by,

$$V_1=\frac{Q}{C_1}=\left(\frac{3\cdot33\times10^{-4}}{5\times10^{-6}}\right)V$$

$$\boxed{Q=CV \quad V=\frac{Q}{C}}$$

$$\Rightarrow \quad V_1=0\cdot666\times10^{2}V=66\cdot6V$$

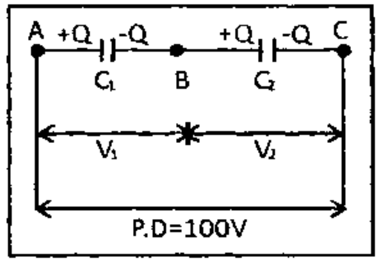
$$\Rightarrow \quad \boxed{V_1=66\cdot6V}$$

(ii) The potential drop across "$C_2$" is given by,

$$V_2=\frac{Q}{C_2}=\frac{3\cdot33\times10^{-4}}{10\times10^{-6}}=3\cdot33\times10^{1}V$$

$$\Rightarrow \quad \boxed{V_2=33\cdot3V}\quad Ans\cdot$$

**Assignment 5: Two capacitors of capacitance 3μF and 6μF are connected in series to a 100V battery. Calculate the equivalent capacitance and the voltage across each capacitor.**




**Solution:**

**Given data:**

Capacitance $= C_1 = 3\mu F = 3\times10^{-6}F$

Capacitance $= C_2 = 6\mu F = 6\times10^{-6}F$

Potential difference $= V = 100V$

**Required:** (a) Equivalent capacitance $= C_e = ?$

(b) Voltage across "$C_1$" $= V_1 = ?$

(c) Voltage across "$C_2$" $= V_2 = ?$

**Calculation:** (a) In each case of series combination, the equivalent capacitance of two capacitors is given by,

$$C_{eq} = \frac{C_1C_2}{C_2+C_1} \text{ ——(1)}$$

Putting the values in equation (1), we get

$$C_{eq} = \left(\frac{3\times10^{-6}\times6\times10^{-6}}{6\times10^{-6}+3\times10^{-6}}\right)F$$

$$\Rightarrow \quad C_{eq} = \left(\frac{18\times10^{-12}}{9\times10^{-6}}\right)F = 2\times10^{-6}F$$

$$\Rightarrow \quad \boxed{C_{eq} = 2\times10^{-6}F} \text{ or } \boxed{C_{eq} = 2\mu F}$$

(b) In series combination, charge remains same, so we have,

$$Q_1 = Q_2 = Q$$

Now $Q = C_eV = 2\times10^{-6}\times100 = 2\times10^{-4}C \Rightarrow Q = 2\times10^{-4}C$

Now voltage a cross "$C_1$" is given by,

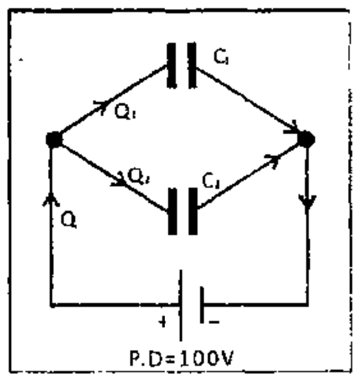
$$V_1 = \frac{Q}{C_1} = \left(\frac{2\times10^{-4}}{3\times10^{-6}}\right)V$$

$\Rightarrow \quad V_1 = 0\cdot666\times10^2 V \Rightarrow \boxed{V_1 = 66\cdot6V}$

(c) Similarly, $V_2 = \frac{Q}{C_2} = \left(\frac{2\times10^{-4}}{6\times10^{-6}}\right)V$

$\Rightarrow \quad V_2 = 0\cdot333\times10^2 V \Rightarrow \boxed{V_2 = 33\cdot3V}$ Ans·

**Example 6: The capacitors of 4µF and 8µF are in parallel· In each case the external source of voltage is 100V· Calculate the total capacitance and the charge on each capacitor·**




Solution:

Given data:

Capacitor= $C_1 = 4\mu F = 4\times10^{-6}F$

Capacitor= $C_2 = 4\mu F = 8\times10^{-6}F$

Voltage $= V = 100V$

Required:

(a) Equivalent capacitance $= C_{eq} = ?$

(b) Charge on "$C_1$" $= Q_1 = ?$

(c) Charge on "$C_2$" $= Q_2 = ?$

Calculation: For parallel combination, the equivalent capacitance is given by,

$$C_{eq} = C_1 + C_2 \text{ ——— } (1)$$

Putting the values in equation (1), we get,

$$C_{eq} = (4\times10^{-6} + 8\times10^{-6})F$$

$$C_{eq} = 12\times10^{-6}F = 12\mu F$$

$\Rightarrow \quad \boxed{C_{eq} = 12\mu F}$

In parallel combination the voltage remains the same

$$V_1 = V_2 = V = 100V$$

In parallel combination the charge splits, the charge

stored in first capacitor "$C_1$" is given by,

$$Q_1 = C_1V \Rightarrow Q_1 = 4\times10^{-6}C\times100V$$

$$\Rightarrow \quad Q_1 = 400\times10^{-6}C = 400\mu C$$

$$\Rightarrow \quad \boxed{Q_1 = 400\mu C}$$

In parallel combination the charge splits, the charge stored in second capacitor "$C_2$" is given by,

$$Q_2 = C_2V \Rightarrow Q_2 = 8\times10^{-6}C\times100V \qquad \boxed{10^{-6} = Micro}$$

$$\Rightarrow \quad Q_2 = 800\times10^{-6}C = 800\mu C$$

$$\Rightarrow \quad \boxed{Q_2 = 800\mu C} \quad Ans.$$

> Assignment 6: Two capacitors of capacitance $3\mu F$ and $6\mu F$ are connected in parallel to a 800V battery. Find the equivalent capacitance and charge on each capacitor.

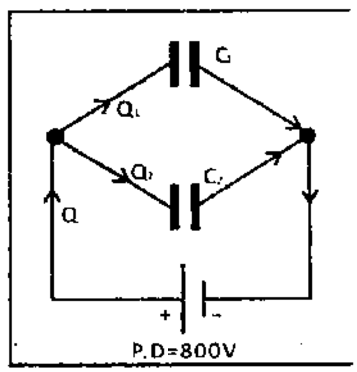
Solution:

Given data:

Capacitance $= C_1 = 3\mu F = 3\times10^{-6}F$

Capacitance $= C_2 = 6\mu F = 6\times10^{-6}F$

Voltage $= V = 800V$




Required:

(a) Equivalent capacitance $= C_{eq} = ?$

(b) Charge on "$C_1$" $= Q_1 = ?$

(c) Charge on "$C_2$" $= Q_2 = ?$

Calculation: (a) For parallel combination, the equivalent capacitance of two capacitors is given by,

$$C_{eq} = C_1 + C_2 \text{ ——(1)}$$

Putting the values in equation (1), we get

$$C_{eq} = \left(3\times10^{-6} + 6\times10^{-6}\right)F$$

$\Rightarrow \quad C_{eq} = (3+6)\times10^{-6}F = 9\times10^{-6}F$

$\Rightarrow \quad \boxed{C_{eq} = 9\times10^{-6}F}$

or $\quad \boxed{C_{eq} = 9\mu F}$

(b) In parallel combination, the voltage remains same, so

$V_1 = V_2 = V = 800V$

Now the charge on "$C_1$" is given by,

$Q_1 = C_1V = \left[3\times10^{-6}\times800\right]C$

$\Rightarrow \quad \boxed{Q_1 = 2400\times10^{-6}C}$

or $\quad \boxed{Q_1 = 2400\mu C}$

Now the charge on "$C_2$" is given by,

(c) $Q_2 = C_2V = \left[6\times10^{-6}\times800\right]C$

$\Rightarrow \quad \boxed{Q_2 = 4800\times10^{-6}C}$

or $\quad \boxed{Q_2 = 4800\mu C}$

## Exercise

Q1: Choose the correct answer.

1. When combing our hair, we shift electrons from our hair onto the comb. The charge on our hairs is:
   a. Positive✓ b. Negative
   c. Zero d. Infinite
2. The unit of charge is:
   a. Farad b. Coulomb✓
   c. Volt d. Electron volt
3. Initially, sphere A has a charge of -50e and sphere B has a charge of +20e. The spheres are made of conducting material and are identical in size. If the spheres then touch, what is the resulting charge on sphere A?
   a. +15e b. -15e✓
   c. +35e d. -35e

**Solution:**

$q_A$ = -50e, $q_B$ = +15e

When both spheres are touched, then out -15e, -15e will be neutralized by +15e. Thus the remaining charge on sphere "A" will be -35e.

4. If the distance between two charged particles is halved, the coulomb force between the two charged particles becomes:
   a. Half b. One quarter
   c. Double d. Four times✓

**Solution:**

$$F = \frac{kq_1 q_2}{r^2} \quad \text{__________(1)}$$

When distance is halved, then $r' = \frac{r}{2}$, so equation (1) becomes

$$F' = \frac{kq_1q_2}{r'^2} \Rightarrow F' = \frac{kq_1q_2}{\left(\frac{r}{2}\right)^2}$$

$$\Rightarrow \quad F' = 4\left(\frac{kq_1q_2}{r^2}\right) \quad \text{________(2)}$$

Putting equation (1) in equation (2), we get,

$$\boxed{F' = 4F}$$

Thus the force become four times if distance is halved.

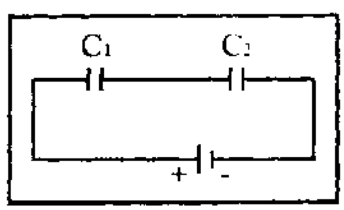
5. The value of coulomb constant k, depends on:
   a. Value of charges
   b. Material medium✓
   c. Separation between charges
   d. All of these

6. An additional capacitor is added to a group of capacitors already connected in series, the equivalent capacitance:
   a. Increase b. Stay the same
   c. Decrease✓ d. Goes to zero

Solution:

For two capacitors connected in series, the equivalent capacitance is given by,

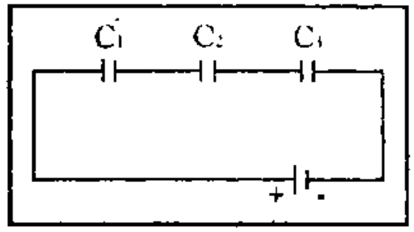
$$\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}} \quad \text{______(1)}$$




If we connect an additional capacitor "$C_3$" in series, then the equivalent capacitance

is given by,

$$\boxed{\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}} \quad \text{———(3)}$$




Equation (2) shows that the equivalent capacitance decreases by adding another capacitor in series.

7. The unit of electric potential is:
   a. Farad  b. Coulomb
   c. Volt✓  d. $NC^{-1}$

8. Four identical 1μF capacitors are connected together electrically. What is the least possible capacitance of the combination?
   a. 4μF  b. 1μF
   c. $\frac{1}{4}$μF ✓  d. $\frac{1}{8}$μF

Solution:

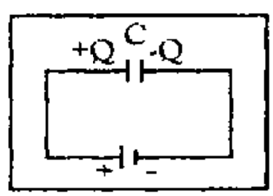
$C_1 = C_2 = C_3 = C_4 = 1\mu F$

If we connect them in series, then

$$\frac{1}{C_{eq}} = \frac{1}{1} + \frac{1}{1} + \frac{1}{1} + \frac{1}{1} = 4 \Rightarrow \frac{1}{C_{eq}} = 4$$

$$\Rightarrow \boxed{C_{eq} = \frac{1}{4}\mu F}$$

9. A capacitor C has a charge Q, the actual charges on its plates are:
   a. Q, Q  b. Q, 0
   c. Q, -Q✓  d. Q/2, -Q/2




Solution:

Actual charge on capacitor having two plates is
+Q, -Q

## Conceptual Questions

Give a brief response to the following questions:

**Q1: Normally, objects with large number of electrons are neutral, why?**

Ans. All objects in their ground state are neutral.

**Reasons and Explanation:**

All the objects are electrically neutral, because they contain equal number of positive charge [protons] and equal number of negative charges [electrons], in their atoms. i.e.

Number of electrons = Number of protons

An object containing large number of electrons will also contain same number of protons. Thus they will neutralized each other as a result the object will remain neutral.

**Q2: How does shuffling feet across a carpet cause hair to stand on our body?**

Ans. When we shuffle feet across a carpet, the hair on our body stands up due to force of repulsion between same charges, present on our body.

**Reasons and Explanation:**

The rubbing of certain materials against one another can transfer negative charges or electrons, i.e. one loses electrons and the other gain that electrons. For example, if we rub a glass rod against a silk cloth, the glass rod losses electrons and becomes positively charged. These electrons are picked up by the silk cloth. In the same way, when we rub (shuffle) our feet on a carpet, we are picking electrons

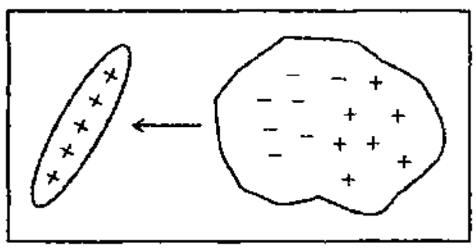
of the carpet and transferring these electrons to our body. These negatively charged particles i.e. electrons are accumulate on our body's hair. As similar charges repel each other, these hair try to repel each other as far away from each other as possible. This is why the hair actually stands up on our body when we rub carpet with our feet.

**Q3: Why neutral objects are always attracted by charged object? Not repelled.**

Ans. Neutral objects are always attracted by charged object due to the phenomenon of electrostatic induction.

Reasons and Explanation:

Since neutral objects also composed of atoms which have negatively charged electrons and positively charged nuclei. When a charged body is brought near a neutral body, then due to electrostatic induction, opposite charge in the neutral body is brought towards the charged body.



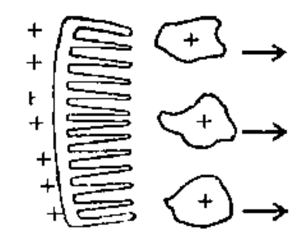
For example, if a positively charged rod is brought near a neutral body, it attracts negative charge in the neutral body towards itself. As we know that opposite charges attract each other, therefore the positively charged rod attracts the (formerly) neutral body towards itself. Thus, we can't conclude that only oppositely charged bodies will attract

each other. A charged body can also attract a neutral body.

**Q4: Why the pieces of paper initially attracted by charged comb fly away when they touch it?**

Ans. In 1st case, the pieces of paper are attracted by charged comb due phenomenon of electrostatic induction.

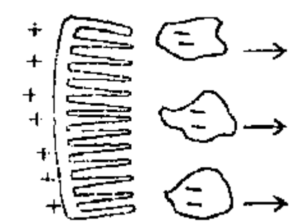
In 2nd case, the pieces of paper fly away from comb due to repulsive force between same charges of comb and pieces of paper.




Case 2: Pieces of paper fly away from comb due to same charge

Reasons and Explanation:

Case-1: When a charged comb is brought near the pieces of paper, negative charges are induced on the pieces of paper due to phenomenon of electrostatic induction. Thus the pieces of paper are attracted by the comb due to electrostatic force of attraction.




Case 2: Pieces of paper fly away from comb due to same charge

Case-2: When the pieces of paper touch the comb, some positive charges are transferred to the pieces of paper. As a result the pieces of paper become positively charged and now there exits electrostatic

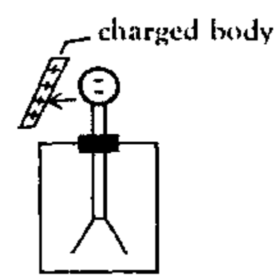
force of repulsion between comb and pieces of paper. As a result, the pieces of paper fly away from the charged comb, as shown in the figure.

**Q5: Is it necessary for a charged body actually to touch the ball of the electroscope for the leaves to diverge? Defend your answer.**

Ans. Yes, the leaves of the electroscope diverge when a charged body touches its ball.

Reasons and Explanation:

Let a positively charged body is brought closer towards the ball of electroscope. Then opposite charges are induced on the ball of electroscope due to the phenomenon of electrostatic induction.




Case 1: Negative charge is induced on ball and thus attracted by charged body.

The charged body attracts the ball due to electrostatic force of attraction. When the ball touches the charged body, some positive charges are transferred to the ball. As a result same charged appears on the leaves of the electroscope and thus they diverge due to electrostatic force of repulsion.

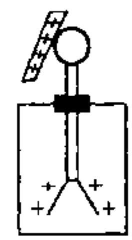
**Q6: How electrostatic painting is better than conventional spray painting?**

Ans. The electrostatic painting is better than conventional spray painting.

Reasons and Explanation:

In electrostatic painting, the paint get charged by

rubbing when passes through the nozzle. Thus the paint particles get the same charge. As a result these paint particles repel each other and spread uniformly on the surface of the body to be painted. These charged paint particles induces opposite charge on the surface of the body due to electrostatic induction. As a result the paint particles are attracted by oppositely charged surface of the body and deposited on it.



Case 2: When ball touches the charged body,some positive charges are transferred to electroscope due to which its leaves diverge.

The electrostatic painting is better than conventional spray painting, because it is effective, efficient and produce uniform and good looking coat than ordinary spray painting.

**Q7: Why are lightning rods normally at higher elevation than the buildings they protect?**

Ans. The lightning rods are normally at higher elevation than the building they protect.

Reasons and Explanation:

Lightning hits the tallest object in its path. For example trees and high buildings.

Now to protect the high buildings from the destructive effects of lightning, the lightning rods are installed at higher elevation than the building. These rods are connected to the copper strips which are buried in the earth. When lightning occurs, the rods provide an easy path to the charges

to be conducted to the earth. In this way, the rods protect the building from the destructive effects of lightning. Thus the lightning rods are stalled at higher elevation than the buildings.

**Q8: What would happen if two insulating plates were used instead of conducting plates to construct a capacitor?**

Ans. If we use two insulating plates in a capacitor then the capacitor would be unable to store charge.

Reasons and Explanation:

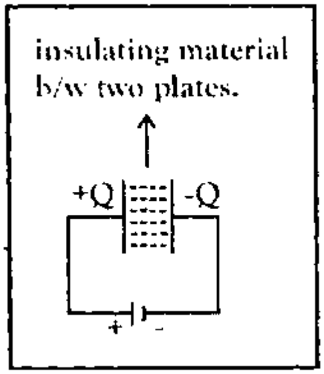
A capacitor is made of two conducting (metal) plates having an insulating material in between them. The metal plates lie very close to each other, but insulating material prevents them from touching. When a potential difference or battery is connected to the plates of the capacitor, its positive terminal draws free electrons from the plate to which it is connected. Thus, this plate acquires a net positive charge on it.

Due to electrostatic induction, equal and opposite charge is induced on the other plate of the capacitor. Thus a capacitor stores equal and opposite charges on its two plates facing each other. This accumulation of charge is very less in case of insulating plates, as insulators have no free electrons. Therefore, only conducting plates are used in a capacitor not insulating ones.

**Q9: The sum of the charges on both plates of a capacitor is zero. What does a capacitor store?**

*Ans. A capacitor store charges, because the oppositely charged plates are separated from each other by insulating material.*

***Reasons and Explanation:***




*When the plates of the capacitor are connected to a battery, one plate charges positively +Q and other negatively -Q which are of the same magnitude. It is true that the sum of these opposite charges of same magnitude is zero when in contact. But in capacitor, these charged plates are separated by insulating medium which are not in contact to conduct the charges, so these oppositely charges remain on the plates of capacitor and hence store the charges.*

> *Q10: If you wish to store a large amount of energy in a capacitor bank, would you connect capacitors in series or parallel? Explain.*

*Ans. We should connect the capacitors in parallel for storing large amount of energy in a capacitor bank.*

***Reasons and Explanation:***

*We know that the energy stored in a capacitor is given by,*

$$E = \frac{1}{2} C_{eq} V^2 \quad \text{______(1)}$$

*Equation (1) shows that for same potential difference "V", the stored energy de-*

> *In series combination, we have*
>
> $$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$$
>
> *In parallel combination, we have,*
>
> $$C_{eq} = C_1 + C_2 + \cdots$$

pends upon the magnitude of equivalent capacitance. i.e. Greater the equivalent capacitance, greater will be the amount of energy stored and vice versa.

Now we know that equivalent capacitance in case of parallel combination is greater than the equivalent capacitance in case of series combination. i.e.

$$\left[C_{eq}\right]_{parallel} > \left[C_{eq}\right]_{series}$$

Thus for storing more energy, the capacitors should be connected in parallel.

## Comprehensive Questions

**1. What is electric charge? How objects can be electrified? Describe with the help of experiments?**

Ans. See answer of question no 1 in the text.

**2. What is electrostatic induction? Explain.**

Ans. See answer of question no 5 in the text.

**3. What is the function of electroscope? How can we use electroscope to find the presence and nature of charge on a body?**

Ans. See answer of question no 6 in the text.

**4. State and explain coulomb's law.**

Ans. See answer of question no 7 in the text.

**5. What is meant by electric field and electric field intensity? How the field lines represent the electric field for isolated positive and negative point charges?**

Ans. See answer of question no 9, 10 in the text.

6. What is electric potential? In what units we measure electric potential?

Ans. See answer of question no 11 in the text.

7. Give some practical applications in which electric field is useful?

Ans. See answer of question no 12 in the text.

8. How lightning occurs? How can we safeguard ourselves from lightning hazard?

Ans. See answer of question no 13 in the text.

9. What is capacitor? Define capacitance and its units.

Ans. See answer of question no 14 in the text.

10. What is series combination of capacitors? How we can determine equivalent capacitors for different capacitors connected in series?

Ans. See answer of question no 15 in the text.

11. What is parallel combination of capacitors? How we can determine equivalent capacitors for different capacitors connected in parallel?

Ans. See answer of question no 16 in the text.

## Numerical Questions

Given an extended response to the following:

Q1: Determine the magnitude of the electric force on the electron of a hydrogen atom exerted by the single proton that is the atom's nucleus. Assume the average distance between the electron and the proton is $r = 5.3 \times 10^{-11}$m and charge on

electrons and proton is $1.6 \times 10^{-19}C$.

Solution:

Given data: Charge on electron = $q_e = 1.6 \times 10^{-19} C$

Charge on proton = $q_p = 1.6 \times 10^{-19} C$

Distance between electron and proton
= $r = 5.3 \times 10^{-11} m$

Coulomb's constant = $k = 9 \times 10^9 Nm^2/C^2$

Required: Magnitude of electric force = $F_e$ = ?

Calculation: We know that,

$$F_e = \frac{kq_1q_2}{r^2} \Rightarrow F_e = \frac{kq_e \cdot q_p}{r^2} \quad \text{———} (1)$$

Putting the values in equation (1), we get,

$$F_e = \left[\frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{(5.3 \times 10^{-11})^2}\right] N$$

$$\Rightarrow F_e = \left[\frac{23.04 \times 10^{-29}}{28.09 \times 10^{-22}}\right] N = \left[0.82 \times 10^{-29+22}\right] N$$

$$\Rightarrow F_e = 0.82 \times 10^{-7} N = 8.2 \times 10^{-8} N$$

Magnitude of electric force = $F_e = 8.2 \times 10^{-8} N$ Ans.

Q2: A 5μC point charge is placed 20cm from a 10μC point charge. (a) Calculate the force experienced by the 5μC charge. (b) What is the force on the 10μC charge? (c) What is the field strength 20cm from the 10μC point charge?

Solution:

Given data:

Charge = $q_1 = 5\mu C = 5 \times 10^{-6} C$

Charge = $q_2 = 10\mu C = 10 \times 10^{-6} C$

Distance between charges = r = 20cm = 0.2m

Coulomb's constant = $k = 9 \times 10^9 N\,m^2/C^2$

**Required:**

(a) Force on $5\mu C$ charge = $F_e$ = ?    Micro = $10^{-6}$

(b) Force on $10\mu C$ charge = $F_e$ = ?

(c) Electric field strength = E = ?

**Calculation:** (a) We know that,

$$F_e = \frac{kq_1q_2}{r^2} \quad ________ (1)$$

Putting the values in equation (1), we get,

$$F_e = \left[\frac{9 \times 10^9 \times 5 \times 10^{-6} \times 10 \times 10^{-6}}{(0.2)^2}\right] N = \left[\frac{450 \times 10^{-3}}{0.04}\right] N$$

$\Rightarrow$ $F_e = 11250.0 \times 10^{-3} N = 11.250N$

$\Rightarrow$ $\boxed{F_e = 11.25N}$

(b) According to equation (1), force on $10\mu C$ will be the same, so

$\boxed{\text{Force on } 10\mu C \text{ charge} = F_e = 11.25N}$

(iii) We know that,

$$E = \frac{F_e}{q_1} \quad ________ (1)$$

Putting the values of "$F_e$" and "$q_1$", we get,

$$E = \frac{11.25}{5 \times 10^{-6}} = 2.25 \times 10^6 \ N/C$$

$\Rightarrow$ $\boxed{E = 2.25 \times 10^6 N / C}$

(OR) E = 2.25 megaN/C    $[10^6 = \text{mega}]$

$\Rightarrow$ $\boxed{E = 2.25MN / C}$

**Answers:**

(i) $\boxed{\text{Force on } 5\mu C \text{ charge} = F_e = 11.25N}$

(ii) $\boxed{\text{Force on } 10\mu C \text{ charge} = F_e = 11.25N}$

(iii) $\boxed{\text{Magnitude of electric field strength} = E = 2.25MN / C}$

**Q3: In a certain region of space, a uniform electric field has a magnitude of $4\cdot60 \times 10^4 N/C$ and points in the positive x-direction. Find the magnitude and direction of the force this field exerts a charge of (a) $+2\cdot80\,\mu C$ (b) $-9\cdot30\,\mu C$.**

Solution:

Given data:

Magnitude of electric field = $E = 4\cdot60 \times 10^4\ N/C$

Charge = $q_1 = 2\cdot80\mu C = 2\cdot80 \times 10^{-6} C$

Charge = $q_2 = -9\cdot30\mu C = -9\cdot30 \times 10^{-6} C$

Required: (a) Magnitude and direction of force exerted on $q_1$ = ?

(b) Magnitude and direction of force exerted on $q_2$ = ?

Calculation: (a) We know that,

$$E = \frac{F_e}{q} \Rightarrow F_e = qE \Rightarrow F_e = q_1E \quad \text{______(1)}$$

Putting the values in equation (1), we get,

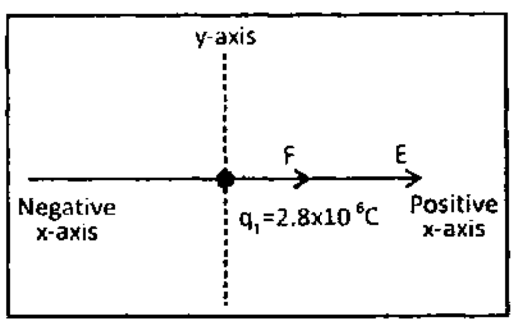
$$F_e = (2\cdot80 \times 10^{-6} \times 4\cdot60 \times 10^4)N$$

$$\Rightarrow \quad F_e = 12\cdot88 \times 10^{-2} N$$

$$= 12\cdot9 \times 10^{-2} N = 0\cdot129N$$

$$\Rightarrow \quad \boxed{F_e = 0\cdot129N}$$

The positive sign of "$F_e$" shows that it is directed towards positive x-axis.




(ii) For "$q_2$" we have,

$$F'_e = q_2E \quad \text{____(2)}$$

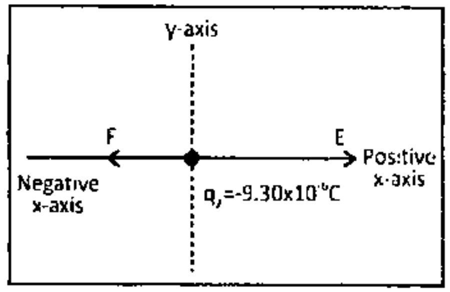
Putting the values in equation (2), we get,

$$F'_e = \left[-9\cdot30 \times 10^{-6} \times 4\cdot60 \times 10^4\right]N$$

$= -42.78 \times 10^{-2} N = -42.8 \times 10^{-2} N$

$\Rightarrow$ $\boxed{F_e' = -0.428N}$

- The negative sign shows that the force is directed towards negative x-axis.




**Answers:**

(i) $\boxed{\text{Force on } q_1 = F_e = 0.129N \text{ (along positive x - axis)}}$

(ii) $\boxed{\text{Force on } q_2 = F_e' = -0.428N \text{ (along negative x - axis)}}$

**Q4: The potential difference between two points is 110V. When an unknown charge is moved between these two points, the work done is 550J. What is the amount of charge?**

**Solution:**

**Given data:** Potential difference = V = 110V

Work done = w = 550J

**Required:** Amount of charge = q = ?

**Calculation:** We know that,

$$V = \frac{w}{q} \Rightarrow q = \frac{w}{V} \quad \text{________}(1)$$

Putting the values in equation (1), we get,

$$q = \frac{w}{V}\left(\frac{550}{110}\right)C = 5C$$

$\Rightarrow$ $q = 5C$

$\boxed{\text{Amount of charge} = q = 5C}$ Ans.

**Q5: The capacitance of a capacitor is 3200pF. If the potential difference between its plates is 220V. What is the charge on each of its plates?**

**Solution:**

Given data: Capacitance = C = 3200pF

$\Rightarrow$ $C = 3200 \times 10^{-12} F$

Potential difference = V = 220V    Pico = $10^{-12}$

Required: Charge on each plate = Q = ?

Calculation: We know that,

$Q = CV$ ______(1)

Putting the values in equation (1), we get,

$Q = \left[3200 \times 10^{-12} \times 220\right] C = 704000.0 \times 10^{-12} C$

$\Rightarrow$ $Q = 0.704 \times 10^{-6} C = 0.704 \mu C$    Micro = $10^{-6}$

Charge on each plate = Q = 0.704μC Ans.

**Q6: Three capacitors of capacitance 1μF, 2μF & 3 μF are connected in series to a 110V battery. Calculate the equivalent capacitance and voltage across each capacitor.**

Solution:

Given data:

Capacitance = $C_1 = 1\mu F$, $\Rightarrow$ $C_1 = 1 \times 10^{-6} F$

Capacitance = $C_2 = 2\mu F$, $\Rightarrow$ $C_2 = 2 \times 10^{-6} F$

Capacitance = $C_3 = 3\mu F$ $\Rightarrow$ $C_3 = 3 \times 10^{-6} F$

Battery voltage = V = 110V

Required: (a) Equivalent capacitance = $C_{eq}$ = ?

(b) Voltage across "$C_1$" capacitor = $V_1$ = ?

(c) Voltage across "$C_2$" = $V_2$ = ?

(d) Voltage across "$C_3$" = $V_3$ = ?

Calculation: (a) For series combination of capacitors, the equivalent capacitance is given by,

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \text{ ______(1)}$$

Putting the values in equation (1), we get,

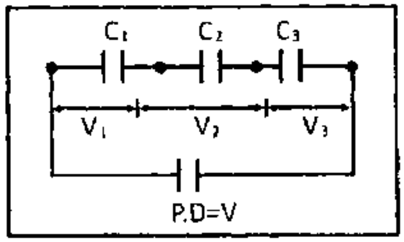
$$\frac{1}{C_{eq}} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3}$$

$$\frac{1}{C_{eq}} = \left(\frac{6+3+2}{6}\right) = \frac{11}{6} \Rightarrow \frac{1}{C_{eq}} = \frac{11}{6}$$

$$\Rightarrow \quad C_{eq} = \frac{6}{11}\mu F = 0.54\mu F$$

$$\Rightarrow \quad \boxed{C_{eq} = 0.54\mu F}$$

(OR) $\boxed{C_{eq} = 0.54 \times 10^{-6} F}$




**Note:** The total charge in the circuit

$= Q = C_{eq}V = (0.54 \times 10^{-6} \times 110)C$

$\Rightarrow \quad Q = 59.5 \times 10^{-6} C = 60 \times 10^{-6} C$

(ii) Now the potential across "$C_1$" is given by,

$$Q = C_1V_1 \Rightarrow V_1 = \frac{Q}{C_1} \quad \text{________(2)}$$

Putting the values in equation (2), we get,

$$V_1 = \left(\frac{60 \times 10^{-6}}{1 \times 10^{-6}}\right)V = 60V$$

$$\Rightarrow \quad \boxed{V_1 = 60V}$$

(iii) The potential across "$C_2$" is given by,

$$V_2 = \frac{Q}{C_2} \quad \text{________(3)}$$

Putting the values in equation (3), we get,

$$V_2 = \left(\frac{60 \times 10^{-6}}{2 \times 10^{-6}}\right)V = 30V$$

$$\Rightarrow \quad \boxed{V_2 = 30V}$$

(iv) The potential across "$C_3$" is given by,

$$V_3 = \frac{Q}{C_3} \quad \text{——— (4)}$$

Putting the values in equation (4), we get,

$$V_3 = \left(\frac{60 \times 10^{-6}}{3 \times 10^{-6}}\right)V = 20V$$

$$\Rightarrow \boxed{V_3 = 20V}$$

**Answers:**

(i) $\boxed{\text{Equivalent capacitance} = C_{eq} = 0.54\mu F}$

(ii) $\boxed{\text{Voltage across "}C_1\text{"} = V_1 = 60V}$

(iii) $\boxed{\text{Voltage across "}C_2\text{"} = V_2 = 30V}$

(iv) $\boxed{\text{Voltage across "}C_3\text{"} = V_3 = 20V}$

**Q7: Two capacitors of capacitance 2pF and 3pF are connected in parallel to a 9V battery. Calculate the equivalent capacitance and the charge on each capacitor.**

**Solution:**

**Given data:**

Capacitance = $C_1$ = 2pF $\Rightarrow$ $C_1 = 2 \times 10^{-12} F$

Capacitance = $C_2$ = 3pF $\Rightarrow$ $C_2 = 3 \times 10^{-12} F$

Battery voltage = V = 9V  $\boxed{\text{Pico} = 10^{-12}}$

**Required:** (i) Equivalent capacitance = $C_{eq}$ = ?

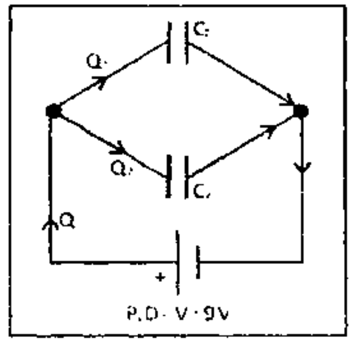
(ii) Charge on "$C_1$" = $Q_1$ = ?

(iii) Charge on "$C_2$" = $Q_2$ = ?

**Calculation:** (i) The equivalent capacitance for pa-

rallel combination is given by,

$C_{eq} = C_1 + C_2$ ________(1)




Putting the values in equation (1), we get,

$C_{eq} = 2pF + 3pF = 5pF$

$\Rightarrow$ $\boxed{C_{eq} = 5pF}$

(ii) Now the charge on "$C_1$" is given by,

$Q_1 = C_1V$ ___________(2)

Putting the values in equation (2), we get,

$Q_1 = 2 \times 10^{-12} \times 9C = 18 \times 10^{-12} C$

$\Rightarrow$ $\boxed{Q_1 = 18 \times 10^{-12} C}$ or $\boxed{Q_1 = 18pC}$

(iii) The charge on "$C_2$" is given by,

$Q_2 = C_2V$ _____________(3)

Putting the values in equation (3), we get,

$Q_2 = (3 \times 10^{-12} \times 9)C = 27 \times 10^{-12} C$

$\Rightarrow$ $\boxed{Q_2 = 27 \times 10^{-12} C}$ or $\boxed{Q_2 = 27pC}$

**Answers:**

(i) $\boxed{\text{Equivalent capacitance} = C_{eq} = 5pF}$

(ii) $\boxed{\text{Charge on "}C_1\text{"} = Q_1 = 18pC}$

(iii) $\boxed{\text{Charge on "}C_2\text{"} = Q_2 = 27pC}$

OOO

- ماں ایک شبنم ہوتی ہے جو کہ زخموں کو ٹھنڈک مہیا کرتی ہے۔
- قوانینِ قدرت سے سر تابی کرنے والے انتقامِ قدرت سے اپنے آپ کو محفوظ نہ سمجھیں۔
- گناہ انسان کا سب سے بڑا دشمن ہے۔
- مصیبت میں آرام کی تلاش مصیبت کو ترقی دیتی ہے۔

CHAPTER 14

# CURRENT ELECTRICITY

**Q1: Define electric current. What is its unit?**
برقی کرنٹ کی تعریف کریں۔ اور اس کی اکائی کیا ہے؟

Ans. Electric Current [برقی کرنٹ]: (BISE Swat 2019)

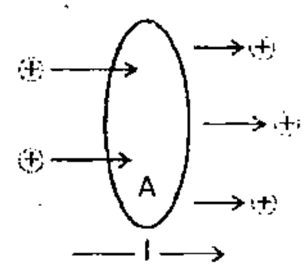
"The rate of flow of charge is known as electric current."

Explanation [وضاحت]

If "Q" is the amount of charge passing through a conductor in time "t", then the current "I" through the conductor is given by,

$$I = \frac{Q}{t} \quad \text{——————} (1)$$

Electric Current




The time rate at which charge flows through the area is defined as the current I.

Unit of Current [کرنٹ کی اکائی]

If Q = 1 coulomb, t = 1sec, then equation (1) becomes,

$$I = \frac{1\ coulomb}{1sec} = 1\ ampere$$

So the unit of current is ampere which is defined as:

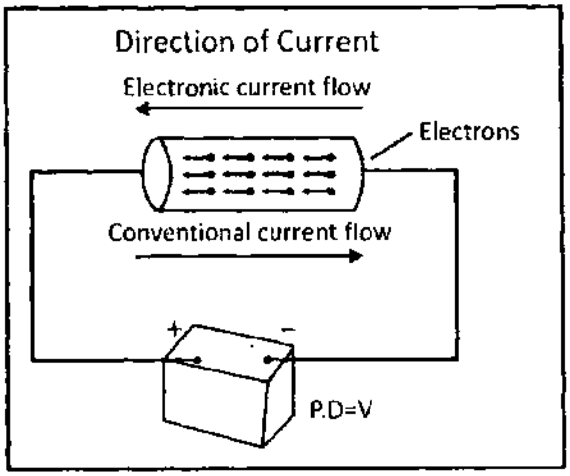
"The current is said to be one ampere if one coulomb charge is flowing through a conductor in one second."

$$1mA = 10^{-3}\,amp$$

$1\mu A = 10^{-6} amp$

**Q2: What is convention current? Explain.**
روایتی کرنٹ کیا ہوتا ہے؟ اس کی وضاحت کریں۔

Ans. Conventional Current [روایتی کرنٹ]




In the beginning, when electrons were not discovered, the scientist though that flow of electric currents occurs due to motion of positive charges only. This idea about current due to motion of positive charges was given the name of conventional current.

Explanation [وضاحت]

Before the discovery of free electrons [negative charges], the scientists thought that electric current is produced only due to the flow of positive charges. Now it is well known that in metals or vacuum tubes current is produced due to flow of free electrons which are negatively charged particles.

In electrolytic solutions, the current can be produced due to flow of negative charges as well as positive charges. In nuclear accelerators, the current is produced due to flow of positive charges i.e. protons.

The magnetic effect of an electric current due to flow of negative charges in one direction is the same as that of the current due to flow of an

equal amount of positive charges in opposite direction. Thus a positive charge moving in one direction is equivalent to a negative charge moving in opposite direction.

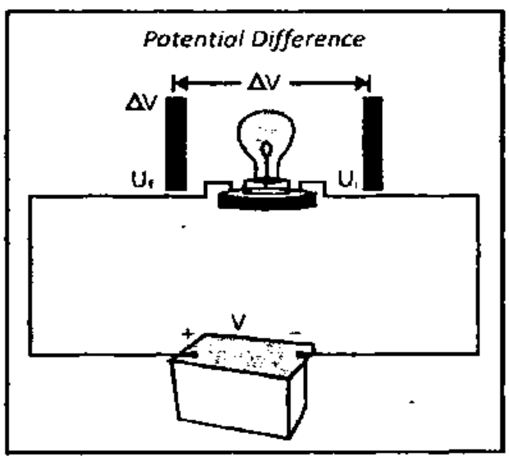
The current which is conventionally considered due to flow of an equivalent positive charge is known as conventional current. The direction of conventional current is taken from positive towards negative terminal of the battery.

**Q3: Define and explain potential difference.**
پوٹینشل کی فرق کی تعریف کریں اور وضاحت کریں۔

Ans. <u>Potential Difference</u>

"The difference in potential energy per coulomb from one side of the resistor to the other side is known as potential difference."

<u>Explanation [وضاحت]</u>




When a conductor is connected across the terminals of the battery, the charge leaving the positive terminal of the battery has potential energy. It losses this P.E in resistor as heat and returns to the negative terminal of the battery with negligible potential energy (P.E). Thus a difference occurs in P.E per coulomb from one side of the resistor to the other side. Such difference in P.E per coulomb is known as potential difference. Its unit is volt.

Definition of Volt

The potential difference is said to be one volt if the potential energy changes in a device at the rate of one joule per coulomb.

**Q4: Define and explain electromotive force (e.m.f).**
الیکٹرو موٹیو فورس کی تعریف کریں اور وضاحت کریں۔

Ans. Electromotive Force (e.m.f): (BISE Mardan 2019)
An electromotive force is a source of energy with the help of which current can be maintained in a closed circuit.

Explanation [وضاحت]

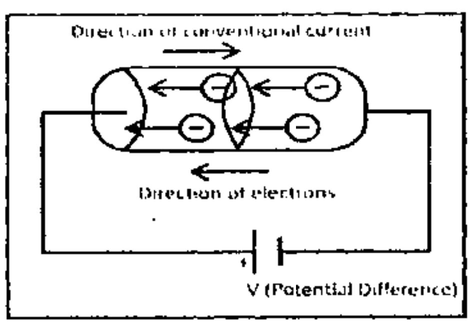
In a certain device, the source of emf can transform non electrical energy into electrical energy. For example, the electric generator is a source of emf, which converts chemical energy into electrical energy. A source of emf is also called "charge pump" because it forces the charges to move around a circuit.

The emf "E" of a source describes the work done per unit charge. Its unit is joule per coulomb or volt.

The emf of a battery is said to be one volt if it gives P.E at the rate of one joule per coulomb.

**Q5: Discuss the flow of current in a conductor.**
کسی موصل تار میں برقی کرنٹ کے بہنے کے عمل کی وضاحت کریں۔

Ans. We know that a conducting wire consists of large number of free electrons. In the absence of external electric field, the net velocity of these



electrons is zero and so no current will flow through the conductor.

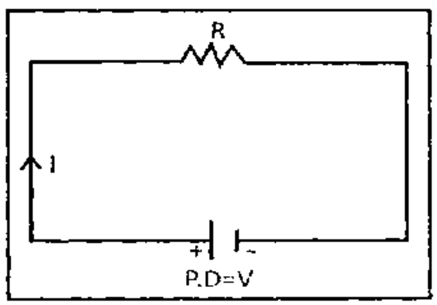
But if we apply external electric field to the conductor by connecting its ends to the terminals of a battery, then the electrons are aligned in proper order and they move in a direction opposite to the electric field. In this way, the current flows through the conductor due to motion of electrons.

**Q6: State and explain ohms law. What are its limitations?**
اوہم کے قانون کی وضاحت کریں اور اس کا اطلاق کس قسم کی اشیاء پر صادق ہوتا ہے؟

Ans. Statement:

(BISE Bannu, Kohat, Malakand, Peshawar, Swat 2019)

This law was presented by German scientist George Simon Ohm in 1826, which states that, "the current through an electrical conductor is directly proportional to the applied voltage, if the temperature and other physical conditions remains constant."




Explanation [وضاحت]

If "V" represents the potential difference and "I" represents the current flowing through the conductor, then according to ohm's law, we have,

$$I \propto V$$

$$\Rightarrow \quad I = Constant \times V \;\Rightarrow\; I = \frac{1}{R}V$$

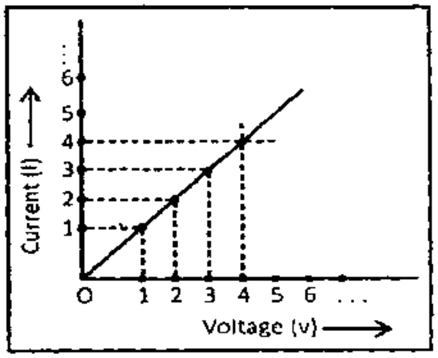
$$\Rightarrow \quad IR = V \;\Rightarrow\; \boxed{V = IR} \text{ ---(1)}$$

Equation (1) represents the mathematical form of ohm's law. In equation (1), "R" is constant and is

known as resistance of the conductor.

**Graphical Representation of Ohm's Law**

If we plot a graph between current and voltage, we get a straight line as shown in the figure.




**Limitations of Ohm's Law**

The ohm's law is valid for metallic conductors, like aluminum, silver, copper etc. But for certain conductors, like electronic tubes, transistors, ionic plasma etc the ohm's law is not valid.

> **Q7: Define electrical resistance of a conductor. On which factors does it depends? What is its unit?**
> کسی موصل تار کی مزاحمت کی تعریف کریں۔ اس کی قیمت کا انحصار کن عناصر پر ہے؟ اکائی بیان کریں۔

Ans. **Resistance [مزاحمت]**: (BISE Bannu 2019)

"The property of a substance which opposes the flow of current through it is known as its resistance."

**Explanation [وضاحت]**

1. The resistance "R" of a conductor depends upon the length of the conductor i.e. greater the length of the conductor, greater will be its resistance and vice versa.
2. The resistance of a conductor also depends upon the area of cross-section of a conductor i.e., greater the area of cross-section of a conductor, smaller will be its resistance and vice versa.
3. The resistance of a conductor also depends upon temperature of a conductor i.e., great-

er the temperature of the conductor, greater will be its resistance and vice versa.

**Unit of Resistance**

As we know that,

$$V = IR \Rightarrow R = \frac{V}{I} \quad ______(1)$$

If $V = 1$ volt, $I = 1$ amp, then equation (1)

$$\Rightarrow \quad R = \frac{1volt}{1amp} = 1\ ohm$$

So the unit of resistance is ohm, which is defined as; "The resistance of a conductor is said to be one ohm if one ampere current is flowing through the conductor by applying a P.D of one volt across its ends."

$$1k\Omega = 10^3\ ohm;\ 1m\Omega = 10^6\ ohm$$

**Q8: Define and explain resistivity (or) specific resistance. What is its unit?**

مزاحمت مخصوصہ کی تعریف اور وضاحت کریں۔ اس کی اکائی کیا ہے؟

Ans. **Resistivity (or) Specific Resistance**

"The resistance of a wire of length 1m and an area of cross-section $1m^3$, is known as resistivity."

**Explanation [وضاحت]**

The resistance of a conductor "R" is directly proportional to the length of the conductor and inversely proportional to the area of cross-section of a conductor. i.e,

$$R \propto L \quad ______(1)$$

$$And\ R \propto \frac{1}{A} \quad ______(2)$$

Combining relations (1) and (2), we get,

$$R \propto \frac{L}{A} \Rightarrow R = Constant\ \frac{L}{A} \Rightarrow R = \frac{\delta L}{A}$$

$$\Rightarrow \boxed{R = \frac{\delta L}{A}} \quad \text{__________(3)}$$

In equation (3), "$\delta$" is constant and is known as resistivity or specific resistance of the conductor.

Unit of Resistivity [مزاحمت مخصوصہ کی اکائی]

From equation (iii), we have,

$$R = \frac{\delta L}{A} \Rightarrow \delta = \frac{RA}{L} \quad \text{__________(4)}$$

Put $R = 1\Omega, A = 1m^2, L = 1m$ in equation (4), we get,

$$\delta = \frac{RA}{L} = \frac{\Omega m^2}{m} = \Omega \cdot m$$

So the unit of resistivity is "$\Omega \cdot m$".

**Q9: What is the effect of temperature on resistance and resistivity of a conductor?**
کسی موصل کی مزاحمت اور مزاحمت مخصوصہ پر درجہ حرارت کا کیا اثر ہوتا ہے؟

Ans. The resistivity and resistance are constant at a particular temperature. But it increases with increase in temperature. This is due to the fact that when the temperature of a conductor increases, then the K.E of vibration of its molecules increases, due to which the amplitude of vibration increases. As a result, greater obstruction occurs in the path of free electrons flowing through the conductor. i.e. the resistance and resistivity of the conductor increases.

**Q10: What do you mean by temperature coefficient of resistance?** مزاحمت کے تھرمل معیار سے کیا مراد ہے؟

Ans. "It is equal to the increase in resistance per

unit resistance per degree centigrade rise in temperature."

Explanation [وضاحت]

Let "$R_o$" represents the resistance of the conductor at zero degree centigrade "0°C". Now if the temperature increases by an amount "$\Delta T$", then the resistance of the conductor becomes "$R_f$". If "$\Delta R$" represents the increase in resistance, then

$$\Delta R \propto R_o \quad \text{__________(1)}$$

And $\Delta R \propto \Delta T$ __________(2)

Combining relation (1) and relation (2), we get,

$$\Delta R \propto R_o \Delta T$$

$$\Rightarrow \quad \Delta R = \text{constant } R_o \Delta T$$

$$\Rightarrow \quad \Delta R = \propto R_o \Delta T \quad \text{__________(3)}$$

In equation (3) " $\propto$ " is constant and is known as temperature coefficient of resistance. From equation (3), we have,

$$\boxed{\propto = \frac{\Delta R}{R_o \Delta T}} \quad \text{__________(4)}$$

Equation (4) that, "the temperature coefficient of resistance is equal to increase in resistance per unit resistance per degree centigrade rise in temperature."

In equation (4),

$\Delta R = R_f - R_o$, so equation (4) can be also written as,

$$\propto = \frac{(R_f - R_o)}{R_o \Delta T} \quad \text{__________(5)}$$

Final Resistance of the Conductor

From equation (iii), we have,

$$\Delta R = \propto R_o \Delta T$$

$$\Rightarrow \quad R_f - R_o = \propto R_o \Delta T$$

$$\left[\Delta R = R_f - R_o\right]$$

$$\Rightarrow \quad R_f = R_o + \propto R_o \Delta T$$

$$\Rightarrow \quad \boxed{R_f = R_o\left[1 + \propto T\right]} \quad \text{____________(6)}$$

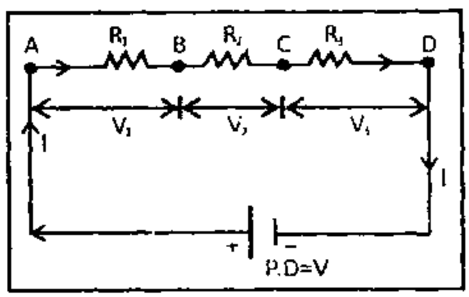
*Equation (6) represents the final resistance of the conductor.*

***Q11: What is series combination of resistance? Discuss the series combination of resistors. How we can determine equivalent resistance for different resistors connected in series? Describe the characteristics features of series combination.***

مزاحمتوں کے سلسلہ وار جوڑ سے کیا مراد ہے؟ مزاحمتوں کے سلسلہ وار جوڑ کی وضاحت کریں۔ سلسلہ وار جوڑ میں لگے ہوئے مختلف مزاحمتوں کا ماحاصل مزاحمت کیسے معلوم کرتے ہیں؟ نیز سلسلہ وار جوڑ کی خصوصیات بیان کریں۔

*Ans.* ***Series Combination***

*"That combination in which current flows along a single path through various resistors is called series combination."*




***Explanation:***

*Consider three resistors $R_1$, $R_2$ and $R_3$ connected in series, as shown in the figure. Now from the given figure, it is clear that there is only one path for the flow of current, while the potential difference 'V' is divided into three parts i.e., $V_1$, $V_2$ and $V_3$ as shown in the figure. So we have,*

$$V = V_1 + V_2 + V_3 \quad \text{____________(1)}$$

*Now we know that,*

$$V = IR \Rightarrow V_1 = IR_1, V_2 = IR_2, V_3 = IR_3$$

*So equation (1)*

$\Rightarrow \quad IR = IR_1 + IR_2 + IR_3 \qquad [I_1 = I_2 = I_3 = I]$

$\Rightarrow \quad IR = I[R_1 + R_2 + R_3]$

$\Rightarrow \quad \boxed{R_{eq} = R_1 + R_2 + R_3}$ ________(2)

*Equation (2) represents the equivalent resistance due to combination of three resistors in series.*

***Equivalent Resistance [ماحاصل مزاحمت]***

*It is that resistance which we get due to combination of two or more than to resistors in series or in parallel. Now if there are N-numbers of resistors, then equation (ii) can be written as,*

$\boxed{R_{eq} = R_1 + R_2 + R_3 + \cdots\cdots + R_n}$ ________(3)

*Equation (3) represents the equivalent resistance due to combination of N-number of resistors in series.*

***Characteristics Features of Series Circuit***

1. *There is a single path for the flow of current.*
2. *The current remains the same in all parts of the circuit.*
3. *The voltage "V" of the circuit is equal to the sum of individual voltage across each resistor.*
4. *The equivalent resistance is equal to the sum of individual resistances.*
5. *The relation between current, voltage and resistance is given by,*

   $\boxed{V = IR}$

6. *The magnitude of equivalent resistance is always greater than the magnitude of any individual resistance connected in the circuit.*

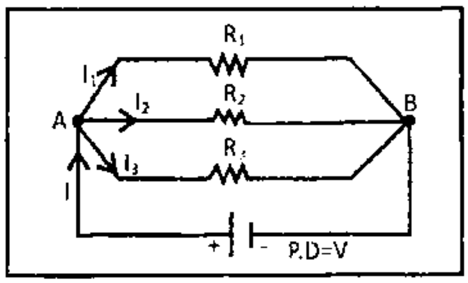
**Q12: What is parallel combination of resistors? How we can determine the equivalent resistance for different resistors connected in parallel? Describe the characteristic features of this combination of resistors?**

مزاحمتوں کے متوازی جوڑ سے کیا مراد ہے؟ متوازی جوڑ میں لگے مختلف مزاحمتوں کا ماحاصل مزاحمت کیسے معلوم کریں گے؟ متوازی جوڑ کے مختلف خصوصیات بیان کریں۔

Ans. **Parallel Combination:** "That combination in which the current flows in various branches and the P.E remain the same is called parallel combination."

**Explanation**

Consider three resistors $R_1$, $R_2$ and $R_3$ which are connected in parallel as shown in the figure.




Here the voltage "V" remains undivided while the current "I" is divided into three parts i.e. $I_1$, $I_2$ and $I_3$ as shown in the figure. So we have,

$$I = I_1 + I_2 + I_3 \quad ________ (1)$$

Now we know that,

$$V = IR \Rightarrow I = \frac{V}{R} \qquad [V_1 = V_2 + V_3 + V]$$

Similarly, $I_1 = \frac{V}{R_1}$, $I_2 = \frac{V}{R_2}$ and $I_3 = \frac{V}{R_3}$

So equation (i) $\Rightarrow$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\Rightarrow \frac{\cancel{V}}{R} = \cancel{V}\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

$$\Rightarrow \boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} \text{———} (2)$$

Equation (2) represents the equivalent resistance due to combination of three resistors in parallel. Now, if there are N-number of resistors, then equation (2) can be written as,

$$\boxed{\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots\cdots + \frac{1}{R_n}} \text{———} (3)$$

<u>Characteristics Features of Parallel Combination</u>

1. There are various paths for the flow of current.
2. The total current "I" is equal to the sum of individual current i.e.,
   $I = I_1 + I_2 + I_3$ etc.
3. The voltage "V" remains undivided.
4. The reciprocal of equivalent resistance is equal to the sum of reciprocal of individual resistances i.e.,
   $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ etc.
5. The magnitude of equivalent resistance is smaller than the magnitude any resistance connected in parallel circuit.
6. The relation between current, voltage and resistance is given by, "$V = IR$"

**Q13: Write a note on conductors and insulators.**
موصل اور غیر موصل اشیاء پر نوٹ تحریر کریں۔

Ans. (1) <u>Conductors [موصل اشیاء]</u> (BISE Bannu 2019)
Those materials through which current can passes easily, are known as conductors.

The metals are generally good conductors. In metals, there are free electrons, which are responsible for the conduction of current in conductors. Aluminum, copper, iron, silver etc are the examples of conductors.

### (2) Insulators [غیر موصل اشیاء]

Those materials through which the current cannot passes are known as insulators.

In insulators, the electrons are tightly bounded to their parent atom. They are not free to move and so they cannot cause conduction of current in the material.

Glass, mica, dry wood, rubber etc are the examples of insulators.

**Q14: What are ohmic and non ohmic devices? Discuss the I-V characteristics graph for ohmic and non-ohmic conductor.**

اوہم اور نان اوہم موصلوں سے کیا مراد ہے؟ اوہم اور نان اوہم موصلوں کیلئے کرنٹ اور وولٹیج (I-V) کی خصوصیات بیان لکھیں۔

Ans. 1) Ohmic Conductors

Those conductors for which ohms law is completely valid are known as ohmic conductors.

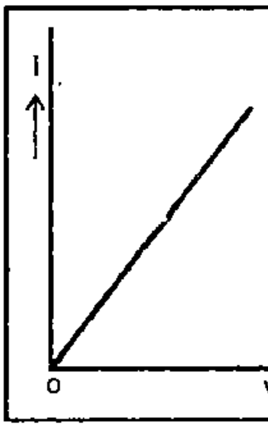


Fig (1)

2) Non-Ohmic Conductors

Those materials for which ohms law is not valid completely are known as non-ohmic conductors.

Some examples of ohmic and non-ohmic conductors

*are given below:*

*1) Metallic Conductors [دھاتی موصل]*

*The metallic conductors are the example of ohmic conductors for which ohm's law is completely valid. i.e.,*

$I \propto V$

*For such conductors, if the voltage becomes double, then the current will also doubled and so on. If we plot a graph for given values of current and voltage, we get a straight line, as shown in figure (1).*

*2) Filament of an Electric Bulb [برقی بلب کا فلامنٹ]*

*The filament of an electric bulb is the example of non-ohmic conductors, for which ohm's law is not valid completely.*

*The increase rate in voltage and current are not the same i.e. for larger increase in voltage, there is smaller increase in current. If we plot a graph between voltage and current we get a bend type curve, as shown in the figure (2).*

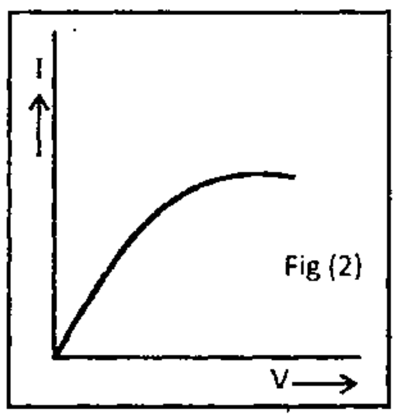
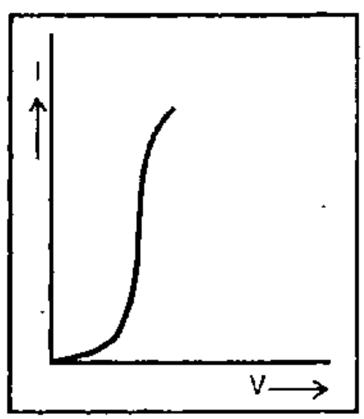


Fig (2)

*3) Thermister [تھرمسٹر]*

*It is a type of resistor whose resistance varies significantly with temperature. If we plot a graph between "V" and "I", we get a curve, as shown in the figure. The graph bends*



upwards, which shows that the resistance decreases sharply with increase in temperature.

> **Q15: Explain the concepts of electric power and electric energy. Discuss their unit. What is the commercial unit for the consumption of electric energy?**
> برقی طاقت اور برقی توانائی سے کیا مراد ہے؟ اس کی پیمائش کے لیے اکائیوں کی وضاحت کریں۔ برقی توانائی کے استعمال کے لیے تجارتی بنیادوں پر کون سی اکائی استعمال ہوتی ہے؟

Ans. Electric Power [برقی طاقت]: "The rate of doing work is known as power."

Explanation [وضاحت]

We know that every conductor offer certain resistance [مزاحمت] in the path of free electrons. So these electrons do work against such resistances. In other words, power is consumed in resistors.

Now we know that,

$$Power = \frac{Work}{Time} \Rightarrow P = \frac{W}{t} \quad \text{________(1)}$$

We also know that, work done in electric field on a unit charge is represents by "V", so the work done on charge "Q" will be;

$$Work = QV \quad \text{________(2)}$$

Putting equation (2) in (1), we get,

$$\boxed{P = \frac{QV}{t}} \quad \text{________(3)}$$

We also know that,

$$\frac{Q}{t} = I \quad \text{________(4)} \qquad [I \rightarrow Current]$$

Putting equation (4) in (3), we get,

$$\boxed{P = IV} \quad \text{________(5)}$$

Putting equation (6) in (5), we get,

$P = I\,IR \Rightarrow \boxed{P = I^2R}$ ________(7)

*Equation (3), (5) and (7) represent the various relations for power to be consumed in resistors.*

*__Units of Power__*

*The S.I unit of power is watt. It is define as, "power is said to be one watt, if one joule work is done in one second." The other units are kilo watt and horsepower.*

$$\begin{bmatrix} 1\text{kilo watt} = 1000\text{ watt} \\ 1\text{ horsepower} = 746\text{ watt} \end{bmatrix}$$

*__Electric Energy [برقی توانائی]__*

*The electric energy is that energy which is produced by generators and is consumed in appliances such as heater, fan, bulb etc.*

*We know that power is consumed in resistors, so as a result, the electrical energy is converted into heat energy, which is given by,*

*Heat energy = Power x Time*

$\Rightarrow \quad W = P \times t$ ________(1)

*Now we know that,*

$P = IV$ ________(2)

*Putting equation (2) in equation (1), we get,*

$\boxed{w = IVt}$ ________(3)

*We also know that,*

$\boxed{P = I^2R}$ ________(4)

*Putting equation (4) in equation (1), we get,*

$\boxed{w = I^2Rt}$ ________(5)

*Equations (3), (4) represents the relations for heat energy which is produced due to power dissi-*

pation in resistors·

<u>Unit of Energy</u>

The units of energy are joules, kilowatt hour, electron volt etc·

$[1kw \cdot hr = 3 \cdot 6 \times 10^6 J, \ 1eV = 1 \cdot 6 \times 10^{-19} J]$

The kilowatt hour is the commercial unit used for the consumption of energy·

**Q16: Discuss Joule's law of heating·** جول کا حرارت کا قانون بیان کریں۔
**(BISE Mardan, Kohat, Malakand 2019)**

Ans· We know that,

$$w = I^2Rt \quad \text{__________} (1)$$

Now the joules law states that,

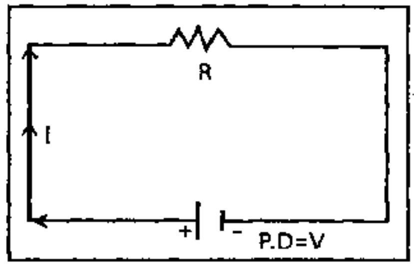
1· The heat dissipated in a conductor is directly proportional to the square of the current, while keeping "R" and "t" constant i·e·, $\boxed{w \propto I^2}$
2· Heat dissipated in a conductor is directly proportional to the resistance of the conductor, while keeping "I" and "t" constant· i·e·, $\boxed{w \propto R}$
3· Heat dissipated in a conductor is directly proportional to the time of flow of current, while keeping "I" and "R" constant· i·e·, $\boxed{w \propto t}$

**Q17: Differentiate between direct current (D·C) and alternating current (A·C)·**
الٹرنیٹنگ کرنٹ اور ڈائریکٹ کرنٹ میں فرق واضح کریں۔

Ans· <u>D·C (Direct Current)</u>

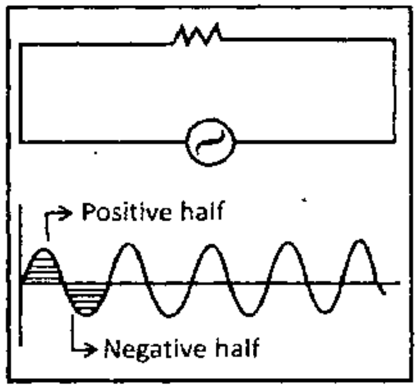
D·C stands for direct current· This type of current always flow in one direction· Such current can be ob-

tained by connecting the ends of the wire to the terminals of a battery.




The D.C flows from positive terminal to the negative terminal of the battery. Its direction always remains the same.

<u>A.C (Alternating Current)</u>




A.C stands for alternating current. Such current changes its direction many times in a second. A.C can be obtained by connecting the resistor in series with a source of alternating voltage.

In A.C, the current changes its direction alternatively from positive half to the negative half, as shown in figure.

<u>Time Period of A.C</u>

The positive half and negative half form one cycle. Now time taken by A.C to complete one cycle is known the time period of A.C. It is denoted by "T".

<u>Frequency of A.C</u>

The number of cycles in one second is known as the frequency of A.C. It is denoted by "f".

<u>Importance of A.C</u>

1. As the A.C changes its direction each time, so it is less dangerous than D.C.
2. A.C can be transmitted more efficiently and economically over long distance.

3. A.C has wider use than D.C.
4. The value of A.C can be changed with the help of transformer.
5. A.C can be converted into D.C very easily.

**Q18: Explain overloading and short circuiting in electricity.**

Ans. From ohm's law, we have,

$$V = IR \Rightarrow I = \frac{V}{R} \quad ______(1)$$

Equation (i) shows that, for high voltage and low resistance, the current flowing in a circuit will be very large. Under such conditions, the voltage source is said to be overloaded, and as a result the voltage source or the wires becomes much heated and there is chance for them to get fire or they may become burst.

In case of short circuiting, the live wire comes in contact with ground or neutral wire due to fault in the wiring. In such a case, very large amount of current will flow in the circuit. The wire becomes heated and they can catch fire.

To avoid such dangerous situation, a fuse wire may be use somewhere in the circuit. Under such conditions, the fuse will melt and break will occur in the circuit. Thus the wiring system and the electric equipments will remain in safe and sound conditions.

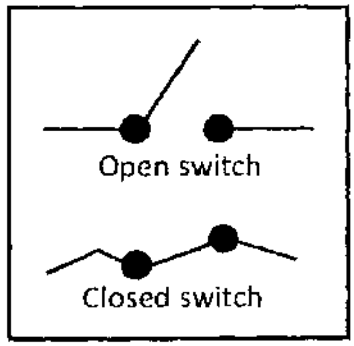
From the above discussion, we can conclude that short circuiting is a special case of overloading.

*Q19: Discuss the various components of a circuit.*
سرکٹ میں جو اجزاء استعمال ہوتے ہیں ان کی وضاحت کریں۔

*Ans.* For the continuous flow of current, we need a certain circuit in which copper wire is connected to batteries, switches, resistors etc. The details are given below:

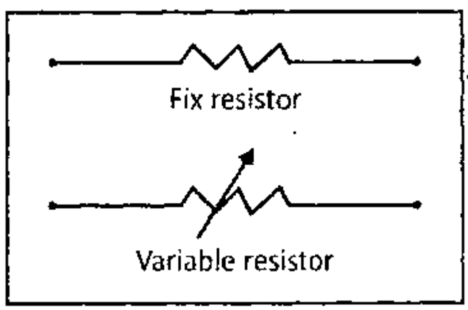
**1) Switches**

It is an electric circuit which control element with two discrete states i.e. "ON" and "OFF" or "closed" and "open". No current flows in the circuit if the switch is open. The current will flow in the circuit if the switch is closed. A closed switch posses zero resistance while an open switch posses infinite resistance.




**2) Resistors**

Resistors are the devices with the help of which we can control the flow of current in a given circuit. It is made from wire coils of special alloys or from carbon.



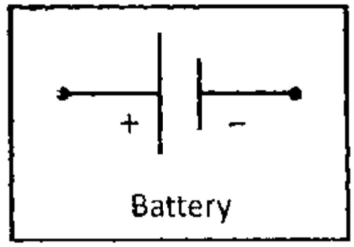

The resistor may be of fixed values as well as of variable values. We can use the variable resistor in two ways. We can use it as a rheostat for changing the current in a given circuit. We can also use it as a potential divider for changing the potential difference [voltage] applied to the circuit.

The unit of resistance is ohm. The resistance of

resistor can be found by measuring the current "I" through it when a P·D "V" is applied across it. Mathematically it is given by,

$$R = \frac{V}{I} \quad \text{__________(1)}$$

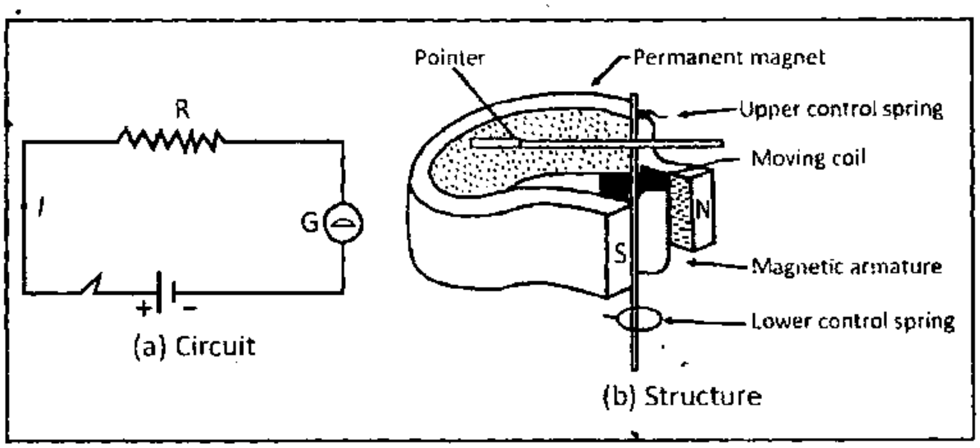
### 3) Batteries




The batteries ensures the continuous flow of current in a circuit. It consists of several cells. We can use battery as a chemical device. We can use battery as a solar cell which converts the heat energy into electrical energy. The battery has the ability to move the charges ir a given circuit and thus we can call it as a charge pump.

**Q20: Write a note on galvanometer.**
**(BISE Bannu, Kohat 2019)** گیلوانومیٹر پر نوٹ تحریر کریں۔

Ans. It is a sensitive electrical device which is used for the measurement of current.




### Construction of Working

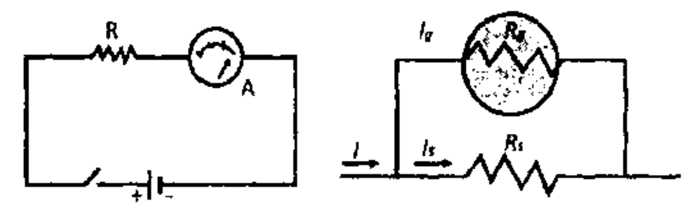
It consists of a coil which is suspended between two poles of a magnet by means of a wire. When

the current passes through the coil, it begins to rotate. This rotation of the coil can be measured with the help of a pointer which moves over a dial. The whole system is enclosed in box with a glass window.

**Q21: Write a note on ammeter.** ایمیٹر پر نوٹ تحریر کریں۔

Ans. It is a modified form of galvanometer which is used for the measurement of large current in a given circuit.

<u>Explanation</u>




(b) Use of ammeter in a circuit (a) Conversion of galvanometer to ammeter

We can modify the galvanometer into ammeter by connecting a low resistance "$R_s$" in parallel with the terminals of galvanometer. Such low resistance is known as shunt resistance '$R_s$'.

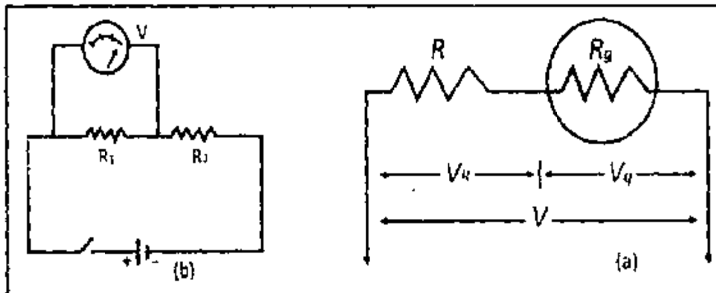
The ammeter is connected in series in a circuit, so that the total current can pass through it for measurement. During measurement, the positive terminal of the source must be connected to the positive terminal of galvanometer, so that the current may not flow in opposite direction. The opposite flow of current can damage the galvanometer.

**Q22: Write a note on voltmeter.** وولٹ میٹر پر نوٹ تحریر کریں۔ **(BISE, Bannu, Kohat 2019)**

Ans. It is a device which is used for the measurement of voltage.

*Explanation*

We can modify the galvanometer into voltmeter by connecting very high resistance "$R_h$" in series with the terminals of galvanometer.



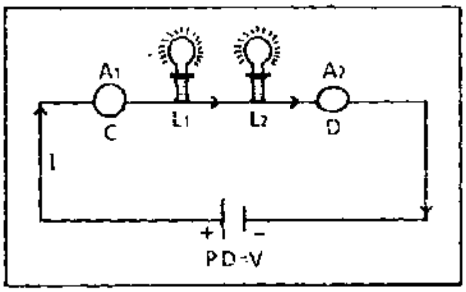

(a) Conversion of galvanometer to voltmeter
(b) Use of voltmeter parallel

The voltmeter is connected in parallel with the circuit resistance. The positive terminal of voltmeter should be connected to that end of resistance which is at higher potential.

**Q23: Write a note on series circuit.**
سلسلہ وار سرکٹ پر نوٹ لکھیں۔

Ans. *Series Circuit* [سلسلہ وار سرکٹ]

It is that circuit in which a single path is available for the flow of current.



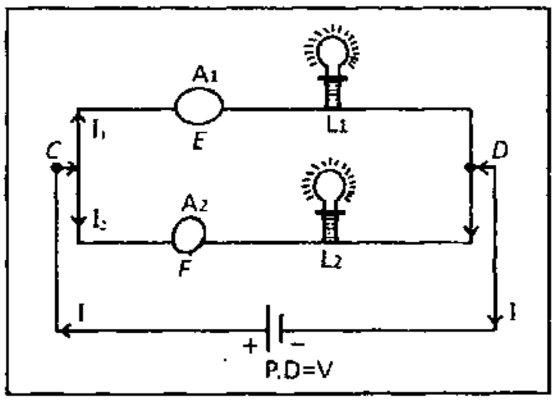

In the given figure, two lamps "$L_1$" and "$L_2$" are connected in series. Two ammeters "$A_1$", "$A_2$" are connected at two different points as shown in the figure.

The ammeter "$A_1$" measures the current at point "C" while the ammeter "$A_2$" measures the current at point "D" respectively. The reading of both ammeters shows that the current remains the same at each point of the circuit.

In case of series combination, the potential drop across each resistor is different. It is because we need different amount of energy to push same number of electrons through different resistors.

**Q24: Write a note on parallel circuit.**
متوازی سرکٹ پر نوٹ تحریر کریں۔

Ans. <u>Parallel Circuit [متوازی سرکٹ]</u>




It is that circuit in which more than one paths are available for the flow of current. In given figure, two lamps "$L_1$" and "$L_2$" are connected in parallel. Two ammeter "$A_1$" and "$A_2$" are connected at point "E" and "F" respectively. When the current "I" reaches at point "C", it is divided into two parts i.e., "$I_1$" and "$I_2$" as shown in the figure.

The ammeter "$A_1$" measures the current "$I_1$" while the ammeter "$A_2$" measure the current "$I_2$" respectively. The sum of "$I_1$" and "$I_2$" gives us the total current "I". i.e.,

$$\boxed{I = I_1 + I_2}$$

The potential difference between point "C" and "D" remains the same. Thus both the lamps are at same potential and thus will provide more illumination as compare to series combination.

**Q25: Discuss the house circuit in detail.**
گھروں میں استعمال ہونے والے سرکٹ کی وضاحت کریں۔

Ans. In houses, we use parallel circuit, because in parallel circuit, the potential difference i.e. voltage "V" remains the same. We can operate any load like T.V, refrigerator, fan, electric iron etc in any part of the house any time due to same voltage.

If we use series combination, then the potential difference "V" will be divided into parts i.e., $V_1$, $V_2$, $V_3$ etc. Under such conditions load like refrigerator, electric iron etc cannot be operated at low voltage. In case of series combination, if we switch ON the circuit, everything connected in the circuit will turn ON, while in case of parallel combination, we can operate any load according to our need and desires.

The appliances [loads] should not be connected to the live and neutral wire directly, because sometime the appliances may be damaged due to excessive current in the circuit. We should use a switch in the form of a socket and plug with any appliances in the circuit. We can operate the appliance by inserting the plug into the socket.

In this way, current will flow through the switch and appliance will be operated. If the current suddenly raised than the required value, then it will damage the switch only and thus the appliance will remain in safe and sound conditions.

**Q26: What are the hazards of electricity? What safety measures are taken in household electricity to safeguard for these hazards?**

بجلی سے متعلق اہم خطرات کی نشاندہی کریں۔ گھروں میں استعمال ہونے والی بجلی سے متعلق احتیاطی تدابیر بیان کریں۔

Ans. The electricity usually comes to our houses by means of a cable. This cable consists of two wires. One wire is called live wire while the other is called neutral wire.

The live wire and any terminal connected to it are very dangerous. Anyone who touches a live wire would suffer a fatal electric shock, because a human body conducts electricity. The electric shocks also occur due to damage insulation from wires, over-heating of cables, damped conditions etc. We should use the switches carefully while operating any appliance in the house.

The electric shock can effect our muscles, eye sight, mental ability. Excessive current can burn our body. If can block our respiratory system due to which we will face certain death. So we should be very careful while using electricity.

**Q27: Discuss the various components used in a circuit. Explain why the domestic appliances are connected in parallel?**

کسی سرکٹ میں استعمال ہونے والے مختلف اجزاء کی وضاحت کریں۔ گھروں میں استعمال ہونے والے برقی اشیاء کو متوازی کیوں جوڑا جاتا ہے؟

Ans. The following components are used in a circuit:

1) <u>Wires and Connectors</u>

Wires and connectors are used to direct current

from one part of the circuit to another. A blob should be drawn where wires are connected. In complex diagrams, it is sometimes necessary to draw crossed wires even when they are not connected. In such cases a bridge; joined and not joined wires are shown in figure (a).

2) Power Supply

Source of electrical energy to the circuit, such as cells and batteries whose symbols are shown in figure (b).

3) Fuse

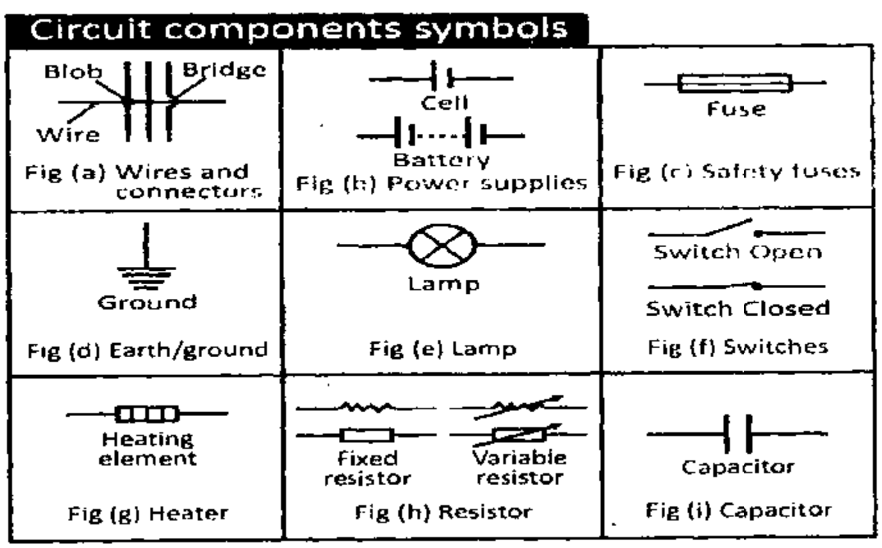
Safety device which blows [melts] if the current through it exceeds a specified value, its circuit symbol is given in figure (c).

4) Earth (Ground)

This is the zero volt connection of a power supply. But for electricity mains and the radio circuits it really means the earth or ground. The circuit symbol is given in figure (d).

5) Lamp

The device which converts electrical energy into light, its circuit symbol is shown in figure (e).



6) Switch

A device that allows or blocks the flow of current. The circuit symbol is shown in figure (f).

7) Heater

A device that converts electrical energy into heat. The circuit symbol is shown in figure (g)

**Explanation about Parallel Connection of Domestic Appliances [گھریلو برقی آلات کا متوازی جوڑ میں استعمال سے متعلق وضاحت]**

In houses, we use parallel circuit, because in parallel circuit, the potential difference i.e. voltage "V" remains the same. We can operate any load like T.V, refrigerator, fan, electric iron etc in any part of the house anytime due to same voltage.

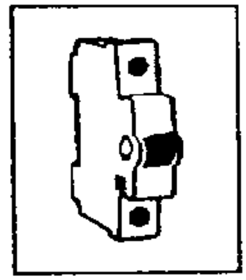
If we use series combination, then the potential difference "V" will be divided into parts i.e., $V_1$, $V_2$, $V_3$ etc. Under such conditions load like refrigerator, electric iron etc cannot be operated at low voltage. In case of series combination, if we switch ON the circuit, everything connected in the circuit will turn ON, while in case of parallel combination, we can operate any load according to our need and desires.

**Q28: Discuss how electricity can be used safely in homes? (OR) Discuss the purpose and usefulness of fuse, circuit breaker and earth wire in electric circuits?**
گھروں میں بجلی کا محفوظ استعمال کیسے کیا جاتا ہے؟ برقی سرکٹ میں فیوز تار، سرکٹ بریکر اور ارتھ تار کی اہمیت بیان کریں۔

Ans. The electricity supplied to our homes is an alternating current which changes its direction about 50 times in a second. Its frequency is 50Hz and its voltage is 220 volt. We should use the following de-

vices in our homes for safe use of electricity:

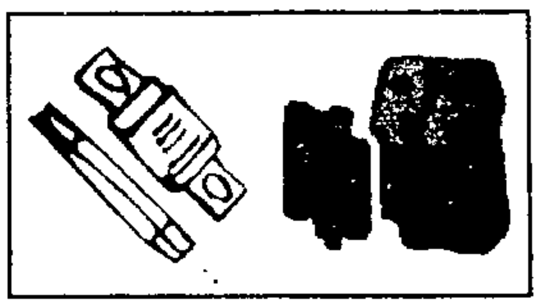
1) Fuse [فیوز]



It is a short piece of thin wire having low melting point· It is connected to the live wire· When very large amount of current flows through the circuit, then it melts due to melting of fuse wire, break occurs in the circuit· In this way, the electric equipments and the circuit wiring remains in safe and sound conditions·

2) Circuit Breaker [سرکٹ بریکر]

It is a modern device which can be used instead of fuse boxes· These are automatic switches which are connected in the live wire· It blocks the current when exceeds above the required value, when the current becomes normal, the breaker turn ON again by pressing the button·



3) Earth Wire [آرتھ تار]

It is a wire, which goes to the top connection on all power sockets and is earthed by being connected either to a metal water pipe in the house or to an earth connection on the supply cable· This wire is a safety precaution to prevent electric shock when an appliance develops a fault·

For example, the element of an electric fire breaks and touches the case, large amount of current flows to earth and blows the fuse· In this way, the appliances remain in safe condition·

## Solution of Examples, Assignments

**Example 1:** A new battery is charged at the battery shop charging station using a current of 6·7A for 5·0h· How much charge passes through to the battery?

**Solution:**

**Given data:** Current = $I = 6{\cdot}7A$

Time = $\Delta t = 5hrs = 5 \times 60 \times 60 = 18000s$

**Required:** Charge = $\Delta Q = ?$

**Calculation:** We know that,

$$I = \frac{\Delta Q}{\Delta t} \Rightarrow \Delta Q = I\Delta t \quad ________ (1)$$

Putting the values in equation (1), we get,

$$\Delta Q = (6{\cdot}7 \times 18000)C \Rightarrow \Delta Q = 120600C$$

$$\boxed{\Delta Q = 1{\cdot}2 \times 10^5 C} \text{ Ans}\cdot$$

**Assignment 1:** While starting an engine of a truck, its battery sets 720C of charge in motion for 4·00s· How much current is flowing?

**Solution:**

**Given data:** Charge = $\Delta Q = 720C$

Time = $\Delta t = 4sec$

**Required:** Current = $I = ?$

**Calculation:** We know that,

$$I = \frac{\Delta Q}{\Delta t} \quad ________ (1)$$

Putting the values in equation (1), we get,

$$I = \frac{\Delta Q}{\Delta t} = \left(\frac{720}{4}\right)A \Rightarrow \boxed{I = 180A}$$

$$\boxed{I = 180A} \text{ Ans}\cdot$$

**Example 2: A 30·0V battery is connected to a 10·0Ω resistor. What is the current in the circuit?**

Solution:

Given data: Potential difference = $V = 30{\cdot}0V$

Resistance = $R = 10{\cdot}0\Omega$

Required: Current = $I$ = ?

Calculation: We know that,

$$I = IR \Rightarrow I = \frac{V}{R} \quad ______ (1)$$

Putting the values in equation (1), we get

$$V = IR \Rightarrow I = \frac{V}{R} = \frac{30}{10} \Rightarrow \boxed{I = 3A}$$

$\boxed{I = 3A}$ Ans.

**Assignment 2: A heating element on an electric range operating on 240V has a resistance of 30·0 Ω. What current does it draw?**

Solution:

Given data: Potential difference = $V = 240V$

Resistance = $30\Omega$

Required: Current = $I$ = ?

Calculation: We know that,

$$V = IR \Rightarrow I = \frac{V}{R} \quad ______ (1)$$

Putting the values in equation (1), we get,

$$I = \frac{V}{R} = \left(\frac{240}{30}\right)A \Rightarrow \boxed{I = 8A}$$

$\boxed{I = 8A}$ Ans.

**Example 3: A small flashlight bulb draws 300mA from its 1·5V battery. What is the resistance of the bulb?**

*Solution:*

*Given data:* Potential difference = $V = 1.5V$

Current = $I = 330mA = 0.3A$

*Required:* Resistance = $R = ?$

*Calculation:* We know that,

$$V = IR \Rightarrow R = \frac{V}{I} \quad \text{________ (1)}$$

Putting the values in equation (1), we get,

$$R = \frac{V}{I} = \left(\frac{1.5}{0.3}\right)\Omega \Rightarrow \boxed{R = 5\Omega}$$

$\boxed{R = 5\Omega}$ Ans.

> *Assignment 3:* Calculate the resistance of wire when the current through it is 2.0A and the voltage across its ends is 3.0V

*Solution:*

*Given data:* Current = $I = 2A$

Potential difference = $V = 3V$

*Required:* Resistance of wire = $R = ?$

*Calculation:* We know that,

$$V = IR \Rightarrow R = \frac{V}{I} \quad \text{________ (1)}$$

Putting the values in equation (1), we get,

$$R = \frac{V}{I} = \left(\frac{3}{2}\right)\Omega \Rightarrow \boxed{R = 1.5\Omega}$$

$\boxed{R = 1.5\Omega}$ Ans.

> *Example 4:* Four resistors $R_1 = 5\Omega$, $R_2 = 12\Omega$, $R_3 = 13\Omega$ and $R_4 = 96\Omega$ are connected in series across a 90V battery. What is the current in the circuit?

*Solution:*

*Given data:*

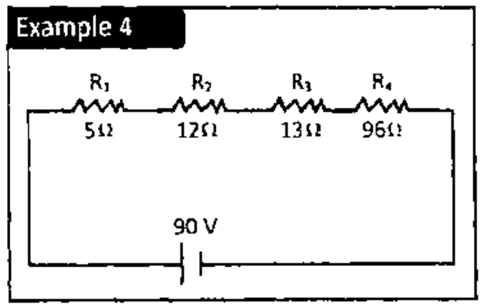
Resistance = $R_1$ = 5Ω

Resistance = $R_2$ = 12Ω

Resistance = $R_3$ = 13Ω

Resistance = $R_4$ = 96Ω

Potential difference = V = 90V




**Required:** Circuit current = I = ?

**Calculation:** For circuit current, first we calculate the equivalent resistance. For series combination the equivalent resistance is given by,

$$R_{eq} = R_1 + R_2 + R_3 + R_4 \quad (1)$$

Putting values in equation (1), we get,

$$R_{eq} = 5\Omega + 12\Omega + 13\Omega + 96\Omega$$

$$\Rightarrow \boxed{R_{eq} = 126\Omega}$$

Now $V = IR_{eq} \Rightarrow I = \frac{V}{R_{eq}} = \left(\frac{90}{126}\right)A$

$$\Rightarrow \boxed{I = 0.71A} \text{ Ans.}$$

**Assignment 4:** Four resistors all having similar resistance of 15Ω are connected in series across a 30V battery. What is the current in the circuit?

**Solution:**

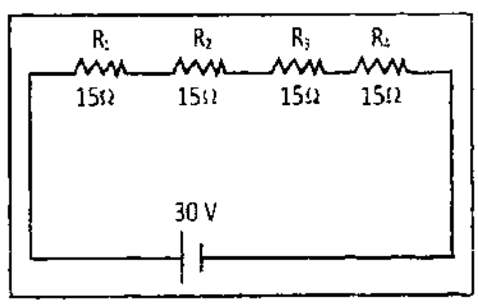
**Given data:**

Resistance = $R_1$ = 15Ω

Resistance = $R_2$ = 15Ω

Resistance = $R_3$ = 15Ω

Resistance = $R_4$ = 15Ω




Voltage of battery = V = 30V

**Required:** Circuit current = I = ?

**Calculation:** For finding the values of circuit cur-

rent, first we calculate the equivalent resistance of the circuit. For series combination, we have,

$$R_{eq} = R_1 + R_2 + R_3 + R_4 \quad ______ (1)$$

Putting the values in equation (1), we get,

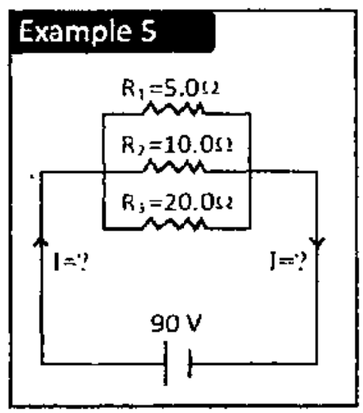
$$R_{eq} = (15 + 15 + 15 + 15)\Omega \Rightarrow \boxed{R_{eq} = 60\Omega}$$

Now the circuit current is given by,

$$V = IR_{eq} \Rightarrow I = \frac{V}{R_{eq}} = \left(\frac{30}{60}\right)A \Rightarrow \boxed{I = 0.5A}$$

$\boxed{I = 0.5A}$ Ans.

**Example 5: Three resistors $R_1 = 5.0\,\Omega$, $R_2 = 10.0\,\Omega$ and $R_3 = 20.0\,\Omega$ are connected in parallel across a 90.0V battery. What is the total current in the circuit?**




__Solution:__

__Given data:__

Resistance = $R_1$ = 5.0Ω

Resistance = $R_2$ = 10.0Ω

Resistance = $R_3$ = 20.0Ω

Potential difference = $V$ = 90V

__Required:__

Total circuit current = $I$ = ?

__Calculation:__ For finding the total circuit current, first we calculate the equivalent resistance of the parallel circuit. For parallel combination, we have,

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad ______ (1)$$

Putting the values in equation (1), we get,

$$\frac{1}{R_{eq}} = \frac{1}{5} + \frac{1}{10} + \frac{1}{20} = \frac{4 + 2 + 1}{20} = \frac{7}{20}$$

$$\Rightarrow \quad \frac{1}{R_{eq}} = \frac{7}{20} \Rightarrow R_{eq} = \frac{20}{7}\Omega \Rightarrow \boxed{R_{eq} = 2{\cdot}9\Omega}$$

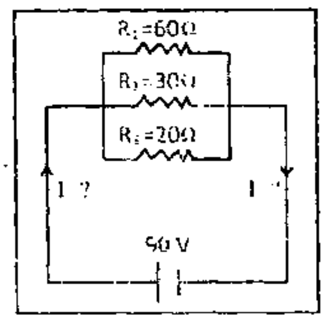
Now the total circuit current is given by,

$$V = IR_{eq} \Rightarrow I = \frac{V}{R_{eq}} = \left(\frac{90}{2{\cdot}9}\right)A \Rightarrow \boxed{I = 31{\cdot}0A}$$

$\boxed{I = 31{\cdot}0A}$ Ans.

> Assignment 5: Three resistors of 60Ω, 30Ω and 20Ω are connected in parallel across a 90V battery. Calculate the current flowing through the circuit.

Solution:




Given data:

Resistance = $R_1$ = 60Ω

Resistance = $R_2$ = 30Ω

Resistance = $R_3$ = 20Ω

Voltage of battery = 90V

Required: Total current in circuit = I = ?

Calculation: For finding the total circuit current, first we calculate the equivalent resistance of the circuit, for which we have,

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \text{ ———— } (1)$$

Putting the values in equation (1), we get,

$$\frac{1}{R_{eq}} = \frac{1}{60} + \frac{1}{30} + \frac{1}{20} = \frac{1+2+3}{60} = \frac{6}{60}$$

$$\frac{1}{R_{eq}} = \frac{6}{60} \Rightarrow R_{eq} = \frac{60}{6}\Omega$$

$$\Rightarrow \quad \boxed{R_{eq} = 10\Omega}$$

Now the circuit total current is given by,

$$V = IR_{eq} \Rightarrow I = \frac{V}{R_{eq}} = \left(\frac{90}{10}\right)A \Rightarrow \boxed{I = 9{\cdot}0A}$$

$\boxed{I = 9{\cdot}0A}$ Ans.

**Example 6:** If a current of 10·0A takes 5 minutes to boil a kettle of water required $3{\cdot}6 \times 10^5 J$ of energy, what is the potential difference [in voltage] across the kettle?

**Solution:**

Given data: Energy = $E = 3{\cdot}6 \times 10^5 J$

Time = $t = 5{\cdot}0min = 300s = 3{\cdot}0 \times 10^2 s$

Current = $I = 10{\cdot}0A$

Required: Voltage = $V$ = ?

Calculation: We know that,

$$E = VIt \Rightarrow V = \frac{E}{It} \quad \text{________}(1)$$

Putting the values in equation (1), we get,

$$V = \left(\frac{3{\cdot}6 \times 10^5}{10 \times 3 \times 10^2}\right)V = 0{\cdot}12 \times 10^3 V$$

$$\Rightarrow \boxed{V = 1{\cdot}2 \times 10^2 V}$$

$\boxed{V = 1{\cdot}2 \times 10^2 V}$ Ans.

**Assignment 6:** For how long a clothes dryer is operated, if it uses 32kJ of energy to dry cloths at 220V, running 16a of current through it?

**Solution:**

Given data:

Energy consumed = $E = 32kJ = 32 \times 10^3 J$

Voltage = $V = 220V$

Current = $I = 16A$

Required: Time for operating the dryer = t = ?

Calculation: We know that,

$$E = VIt \Rightarrow t = \frac{E}{VI} \quad \text{________}(1)$$

Putting the values in equation (1), we get,

$$t = \left(\frac{32 \times 10^3}{220 \times 16}\right)sec = 9{\cdot}09sec \Rightarrow \boxed{t = 9{\cdot}09sec}$$

$\boxed{t = 9{\cdot}09sec}$ Ans.

**Example 7: In the flashlight the current is 0·40A, and the voltage of 3·0V is delivered by cell. Find the power delivered to the bulb.**

Solution:

Given data: Current = $I = 0{\cdot}40A$

Voltage = $V = 3{\cdot}0A$

Required: Electric power = P = ?

Calculation: We know that,

$$P = IV \quad \text{________}(1)$$

Putting the values in equation (1), we get,

$$P = (0{\cdot}40 \times 3)\,watt \Rightarrow \boxed{P = 1{\cdot}2\,watt}$$

$\boxed{P = 1{\cdot}2\,watt}$ Ans.

**Assignment 7: Calculate the resistance of a 40W automobile designed for 12V.**

Solution:

Given data: Power = P = 40 watt

Voltage = V = 12V

Required: Resistance = R = ?

Calculation: We know that,

$$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} \quad \text{________}(1)$$

Putting the values in equation (1), we get,

$$R = \frac{(12)^2}{40} = \left(\frac{144}{40}\right)\Omega \Rightarrow \boxed{R = 3\cdot6\Omega}$$

$\boxed{R = 3\cdot6\Omega}$ Ans·

**Example 8:** You are arranging night cricket tournament, you have arranged five 1000W light bulbs· These bulbs will remain lit for 6 hours for 29 days· Estimate the cost of electricity consumption if the cost of electricity is 8·11Rs/kWh·

Solution:

Given data: Power of one bulb = 1000W

Power of five bulbs = P = 5 x 1000W

= 5000W = 5kW

Time = t = 29 x 6h = 174h

Tariff rate = T·R = 8·11Rs/kWh

Required: (i) Energy consumed = $E_{(kWh)}$ = ?

(ii) Cost of electricity = C = ?

Calculation: (i) We know that,

$$E = P \times t \quad \text{________}(1)$$

Putting the values of "P" and "t" in equation (1), we get,

$$E = (5 \times 174)kW\cdot hr$$

$$\Rightarrow \boxed{E = 870\ kW\cdot hr}$$

(ii) Cost of electricity = energy consumed x tariff rate

$$\Rightarrow C = E \times T\cdot R = (870 \times 8\cdot1)Rs = 7055\cdot7Rs$$

$\boxed{C = 7055\cdot5Rs}$ Ans·

ہماری نجات کا راستہ صرف اور صرف اُسوۂ حسنہ ہے۔

**Assignment 8:** A 100W bulb is left on, in an outdoor storage room to keep paint from freezing. The 100W rating refers to the power dissipated in the bulb's filament, which is a resistor. If electricity costs 8.11Rs/ kWh, about how much does it cost to burn the light bulb for three months during winter?

Solution:

Given data:

$Power = P = 100W = 0.1 \times 10^3 W = 0.1kW$

$Time = t = 3\ months = 90\ days = 90 \times 24hr$

$\Rightarrow\ t = 2160hr$

$Tariff\ rate = T.R = 8.11\ Rs/kWh$

Required:

$Cost\ of\ electricity = C = ?$ $\quad$ $\boxed{1day = 24\ hr}$

Calculation: We know that,

$Cost\ of\ electricity = energy\ consumed \times tariff\ rate$

$\Rightarrow\ C = E \times T.R$

$\Rightarrow\ C = P \times t \times T.R$ $\quad$ $[E = P \times t]$

$\Rightarrow\ C = (0.1 \times 2160 \times 8.11)Rs$

$\Rightarrow\ \boxed{C = 1751.76Rs}$

$\boxed{Cost = C = 1751.76\ Rs}$ Ans.

⊛ ترقی کا راز لگاتار عمل اور تکرار عمل میں پوشیدہ ہوتا ہے۔

⊛ بہترین قول ذکر الٰہی، بہترین عمل عبادتِ الٰہی اور بہترین خصلت علم ہے۔

## Exercise

Q1: Choose the correct answer.

1. Batteries are rated with unit ampere – hour, it is the unit of:
   a. Charge✓  b. Current
   c. Power  d. Energy
2. When connected to a battery, a light bulb glows brightly, if the battery is reversed and connected to the bulb, the bulb will glow.....
   a. Brighter  b. Dimmer
   c. With the same brightness✓
   d. and fuse
3. The resistance of wire will decrease by increasing:
   a. Temperature  b. Length
   c. Diameter✓  d. Both a & b

Solution:

$$R = \frac{\delta L}{A} = \frac{\delta L}{\pi r^2} = \frac{\delta L}{\pi\left(\frac{d}{2}\right)^2} = \frac{4\delta L}{\pi d^2} \qquad \boxed{A = \pi r^2, \; r = d/2}$$

$$\Rightarrow \quad R \propto \frac{1}{d^2} \quad ________(1)$$

Relation (1) shows that when diameter "d" increases, the resistance decreases.

4. The wire made from which of the following material is a conductor.
   a. Glass  b. Rubber
   c. Silver✓  d. Silk
5. The current which reverses direction after regular interval of time is:

a. DC b. AC✓
c. Conventional current d. Both a & b

6. Electricity main supply meters measures it in units of kilowatt – hour; it is the unit of:
a. Charge b. Current
c. Power d. Energy✓

7. The device that is used to protect a circuit against overload is:
a. Heater b. Fuse✓
c. Lamp d. All of these

8. Which of the following represent one ohm?
a. $VA^{-1}$✓ b. $JS^{-1}$
c. $WA^{-1}$ d. $JC^{-1}$

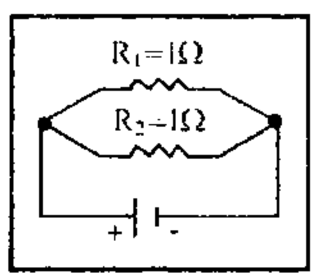
*Solution:*

$$V = IR \Rightarrow R = \frac{V}{A} = \frac{Volt}{Ampere} = \frac{V}{A} = (VA^{-1})$$

9. Two resistances of 1ohm are connected in parallel, the equivalent resistance is:
a. 2Ω b. 1.5Ω
c. 1Ω d. 0.5Ω✓

*Solution:*

For parallel combination, the equivalent resistance is given by,




$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_1} = \frac{1}{1} + \frac{1}{1} = 2$$

$$\Rightarrow \frac{1}{R_{eq}} = 2 \Rightarrow R_{eq} = \frac{1}{2}\,ohm$$

$$\Rightarrow \boxed{R_{eq} = 0.5\ ohm}$$

10. 1kWh =......

a. 3600W    b. 1000J

c. $3.6 \times 10^6$J ✓    d. 0.36 hrs

Solution:

1Kwatt. Hour

= 1 x 1000 x watt . 3600sec

$= 1 \times 1000 \times \frac{J}{sec} \times 3600sec$

$= 3600 \times 1000J = 3.600 \times 10^3 \times 1000J$

$= 3.6 \times 10^3 \times 10^3 J = 3.6 \times 10^6 J$

$P = \frac{w}{t} = \frac{J}{sec} = watt$

Kilo = 1000

1hour = 3600sec

## Conceptual Questions

Give a brief response to the following questions:

**Q1: As water is made of atoms having protons (charge +e) and electrons (charge −e). Does the water flowing through pipe carry an electric current? Explain?**

Ans. The water flowing through pipe carry no current.

Reasons and Explanation:

The water molecules consist of atoms. These atoms contain positive charges [protons] and negative charges [electrons]. These charges neutralize each other. As a result the whole atoms become neutral. There is no net charge to flow. Thus the water flowing through the pipe contains neutral atoms, and carry no current through the pipe.

*Q2: A car has two headlights, when the filament in one headlight burns out, the other headlight stays on. Are the headlights connected in series or in parallel?*

*Ans. The headlights of the car are connected in parallel.*

*Reasons and Explanation:*

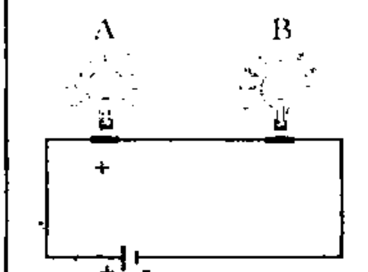


Fig (a)

*Consider two light bulbs "A" and "B" connected in series as shown in the figure (a). When the switch is ON, both bulbs "A" and "B" will glow. Now if the filament of bulb "A" burns out, then bulb "B" will also becomes OFF. It is because, there is only one path for the flow of current. Thus if bulb "A" is damaged, it will also cut off the flow of current towards bulb "B" and as a result bulb "B" will also remains OFF.*

*Now let the two bulbs are connected in parallel as shown in figure (b). In this case the current "I" is divided into two parts at point "C". Current "$I_1$" flows through bulb "A" and "$I_2$" flows through bulb "B". Now if the filament of bulb "A" burns out, it will become OFF. But bulb "B" will still remain ON. It is because the circuit of bulb "A" does not affect the current "$I_2$" passing through bulb "B". The circuit of bulb "A" and circuit of bulb "B" are independent of each other.*

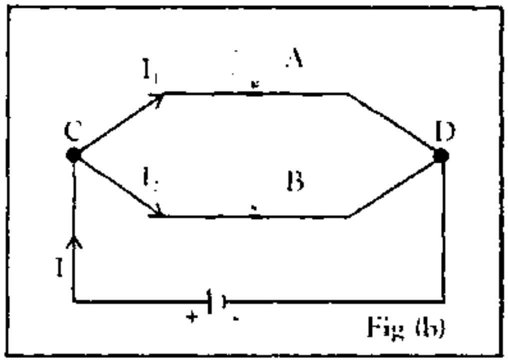


Fig (b)

*Conclusion:* From the above discussion it is clear that the headlight of the car should be connected in parallel. Under such condition, if one headlight is damaged and becomes OFF, then the other headlight will remain unaffected and will remain ON.

**Q3: Qurat-ul-Ain needs a 100Ω resistor for a circuit, but she only has a box of 300Ω resistors. What can she do?**

Ans. She should connect the resistors in parallel.

*Reasons and Explanation:*

In order to get an equivalent resistance of 100Ω, she will connect the three resistors each of 300Ω in parallel.

*Proof:* Consider three resistors $R_1 = R_2 = R_3 = 300\Omega$ are connected in parallel as shown in the figure. The equivalent resistance of these resistors is given by,

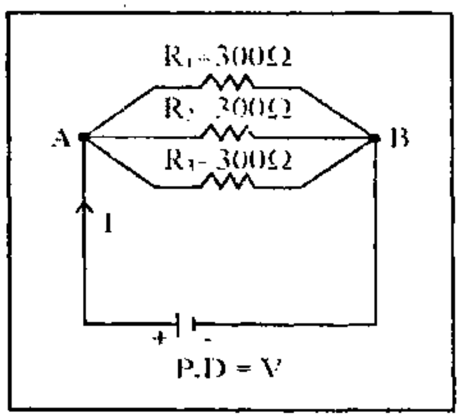
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\Rightarrow \quad \frac{1}{R_{eq}} = \frac{1}{300} + \frac{1}{300} + \frac{1}{300}$$

$$= \frac{1+1+1}{300} = \frac{3}{300} = \frac{1}{100}$$

$$\Rightarrow \quad \frac{1}{R_{eq}} = \frac{1}{100}$$

$$\Rightarrow \quad \boxed{R_{eq} = 100\Omega}$$



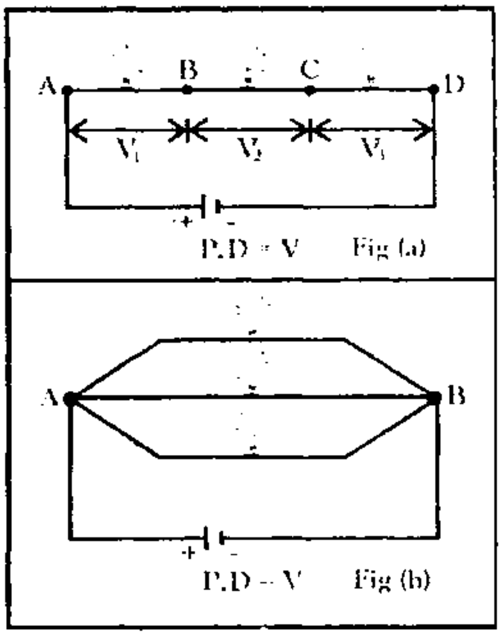
Thus she must connect the three resistors in parallel for getting an equivalent resistance of 100Ω.

**Q4: A number of light bulbs are connected to a single power outlet. Will they provide more illumination when connected in series or in parallel, why?**

Ans. For getting more illumination, the light bulbs should be connected in parallel.

Reasons and Explanation:

Consider the combination of three bulbs in series and then in parallel as shown in the figure. In case of parallel combination the light bulb will give more brightness as compare to series combination. It is because,




1. In case of series combination, the potential difference "V" is divided into $V_1$, $V_2$ and $V_3$. While in case of parallel combination, the potential difference remains undivided. Thus the potential difference across each bulb remains the same and all bulbs give the same brightness.
2. In case of series combination, the equivalent resistance increases. As a result the current in the circuit decreases and the bulbs remain dim. While in parallel combination, the equivalent

resistance decreases. As a result more current flows in the circuit and the bulbs produce maximum brightness.

Conclusion: From the above discussion, it is clear that for getting more brightness, the light bulb should be connected in parallel.

**Q5: Explain why light bulbs almost always burn out just as they are turned ON and not after they have been ON for some time?**

Ans. (a) Light bulbs almost burn out just as they are turned ON.

(b) When light bulbs remain ON for some time, they does not burn out.

Reasons and Explanation:

Part-a: When we turn ON light bulbs at room temperature, its filament is cold and thus having low resistance. As a result large current flows through the filament which causes great heating effect. Due to excessive heating, the filament melts and hence burns.

Part-b: When the current in the filament of the bulb flows for some time, its resistance increases due to heating. The increase in resistance controls the flow of excessive current. As a result the filament remains safe due to control current and gives light continuously.

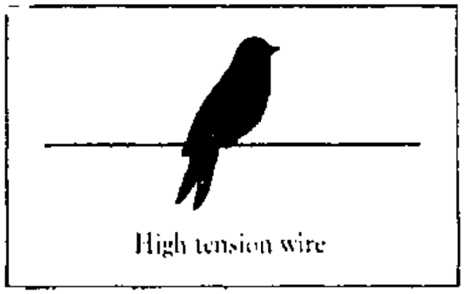
**Q6: Explain why is it possible for birds to perch safely on high tension wires without being electrocuted?**

Ans. It is possible for birds to perch safely on high

tension wires without being electrocuted.

Reasons and Explanation:

The current flows from one body to another due to potential difference between the two bodies.




The birds which perch on the high tension wires are safe because the potential at every point on the high tension wires is same. When the birds perch on high tension wire, their claws are at same potential due to which no current flow through their bodies and so not electrocuted.

**Q7: An electrician working on live circuits wears insulated shoes and keep one hand behind his or her back? Why?**

Ans. An electrician working on live circuits wears insulated shoes and keep one hand on back to prevent himself from electric shocks.

Reasons and Explanation:

Part (a): The live circuits are at high potential while the earth is at low or zero potential.

Now an electrician working on live circuits wears insulated shoes. The insulated shoes prevent the flow of current into the body of electrician and thus remain safe from any electric shock. If the electrician wears conducted shoes or working with bare feet, then due to potential difference between earth and live wire, current may flow through his body and as a result he will suffer from dangerous

electric shock.

Part (b): The electrician keep his one hand on his back to prevent himself from touching other conducting material present in the surroundings. In this way, the electrician will be able to prevent himself from any electric shock.

**Q8: Explain why is it dangerous to turn ON a light bulb when you are in a bath tub?**

Ans. It is dangerous to turn ON a light bulb when someone is in a bath tub.

Reasons and Explanation:

A man sitting in a bath tub placed on earth is at zero potential. While the electric switch is at high potential. Now if a man sitting in a bath tub touches a leak switch, there is a chance that the electric current may flow through his body due to potential difference between from switch and the person. As a result the person will suffer dangerous electric shock. Thus it is dangerous to turn ON light bulb when somebody is in a bath tub.

**Q9: Why circuit breaker, fuses and switches are installed to live wire?**

Ans. Circuit breaker, fuses and switches are installed to live wire to prevent the circuit from any damage.

*Reasons and Explanation:*

*1· Function of Circuit Breaker:*

*The circuit breakers are installed in electric circuits for safety purposes· When some fault or short circuiting occurs in a circuit, large amount of current flows in the circuit which can damage any electric device· The circuit breaker is a device which switch OFF the flow of current through any electric device when short circuit or other fault exist in a circuit·*

*2· Function of Fuses:*

*It is another device which can be used in an electric circuit for safety purposes· The fuse consists of thin piece of metal wire having low melting temperature· This fuse is installed in series to main supply live wire· In case of short circuit in wiring when the current exceed the specified value, the fuse wire heated up and melts which break the supply line and thus prevent the fire in house wiring·*

*3· Function of Switches:*

*In the houses the electric appliance are connected in parallel between live wire and neutral wire through the switches· Every switch is made to allow the specified value of current to flow· If the current exceed from the specified value the switch is heated up and damages which break the circuit and thus prevent the device·*

## Comprehensive Questions

*Given an extended response to the following questions:*

**1. Define electric current. In what units it is measured? Discuss briefly the direction of current through the conductor.**

Ans. See answer of question no 1, 5 in the text.

**2. What is potential difference and emf? Differentiate between them.**

Ans. See answer of question no 3, 4 in the text.

**3. State and explain ohm's law. What are its limitations?**

Ans. See answer of question no 6 in the text.

**4. What is resistance and in what units we measure resistance?**

Ans. See answer of question no 7 in the text.

**5. What is series combination of resistors? How we can determine equivalent resistance for different resistors connected in series?**

Ans. See answer of question no 11 in the text.

**6. What is parallel combination of resistors? How we can determine equivalent resistance for different resistors connected in parallel?**

Ans. See answer of question no 12 in the text.

**7. Explain the factors on which the resistance of metallic conductor depends?**

Ans. See answer of question no 7 in the text.

8· What are ohmic and non-ohmic devices? Sketch and interpret the VI characteristic graph to justify metallic conductor, filament lamp and thermistor as ohmic or non-ohmic materials·

Ans· See answer of question no 14 in the text·

9· Explain the concept of electric energy and electric power· What is the commercial unit for the consumption of electric energy?

Ans· See answer of question no 15 in the text·

10· State the functions of live, neutral and earth wires in domestic main supply· Explain why the domestic appliances are connected in parallel?

Ans· See answer of question no 27 in the text·

11· Differentiate between alternating current and direct current·

Ans· See answer of question no 17 in the text·

12· What are the hazards of electricity? What safety measures are taken in household electricity to safeguard for these hazards?

Ans· See answer of question no 26 in the text·

## Numerical Questions

**Q1: A small electric heater has a resistance of 15 ohms when the current in it is 2 amperes. What voltage is required to produce this current?**

Solution:

Given data:

Resistance = $R = 15\Omega$

Current = $I$ = 2 ampere

Required:

Voltage = $V$ = ?

Calculation:

We know that,

$V = IR$ ___________(1)

Putting the values in equation (1), we get,

$V = (2 \times 15)V = 30V \Rightarrow V = 30V$

$\boxed{\text{Voltage} = V = 30V}$ Ans.

**Q2: If a potential difference of 10V in maintained across a 1m length of the Nichrome wire having resistance of 3.1Ω, what is the current in the wire?**

Solution:

Given data:

Potential difference = $V = 10V$

Length of wire = $L = 1m$

Resistance = $R = 3.1\Omega$

Required:

Current in the wire = $I$ = ?

*Calculation:*

*We know that,*

$$V = IR \Rightarrow I = \frac{V}{R} \quad _______(1)$$

*Putting the values in equation (1), we get,*

$$I = \left(\frac{10}{3\cdot 1}\right)A = 3\cdot 22A = 3\cdot 2A$$

Current in the wire = $I = 3\cdot 2A$ Ans.

**Q3: What resistor would have a 15mA current if connected across the terminals of a 9·0V battery?**

*Solution:*

*Given data:*

Current = $I = 15mA = 15 \times 10^{-3}A$

Voltage of battery = $V = 9\cdot 0V$

*Required:*

Resistance = $R$ = ?

*Calculation:*

*We know that,*

$$V = IR = R = \frac{V}{I} \quad _______(1)$$

*Putting the values in equation (1), we get,*

$$R = \left(\frac{9}{15 \times 10^{-3}}\right)\Omega = 0\cdot 6 \times 10^{3}\Omega = 600\cdot 0\Omega$$

Resistance = $R = 600\Omega$ Ans.

**Q4: Consider a circuit with three resistors $R_1$ = 250·0Ω, $R_2$ = 150·0Ω, $R_3$ = 350·0Ω, connected in parallel with a 24·0V battery. Find the total current supplied by the battery.**

*Solution:*

*Given data:*

Resistance = $R_1$ = 250Ω

Resistance = $R_2$ = 150Ω

Resistance = $R_3$ = 350Ω

Voltage of battery = V = 24V

*Required:*

Total current = I = ?

*Calculation:*

For finding total current, we need the equivalent resistance of the circuit. The equivalent resistance of parallel combination is given by,

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{250} + \frac{1}{150} + \frac{1}{350}$$

$$\Rightarrow \quad \frac{1}{R_{eq}} = \frac{21 + 35 + 15}{5250} = \frac{71}{5250}$$

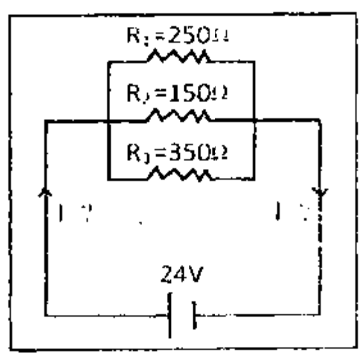
$$\Rightarrow \quad R_{eq} = \frac{5250}{71}\,\Omega \Rightarrow R_{eq} = 73.9\Omega$$

$$\Rightarrow \quad \boxed{R_{eq} = 74\Omega}$$

Now we know that,

$$V = IR_{eq}$$

$$\Rightarrow \quad I = \frac{V}{R_{eq}} \quad \text{———— (1)}$$




Putting the values of "V" and "$R_{eq}$" in equation (1), we get,

$$I = \left(\frac{24}{74}\right)A = 0.3A$$

$$\boxed{\text{Total current} = I = 0.3A}$$ Ans.

*Q5: An electric hair dryer is rated at 1,875 watts when operating on 120 volts. What is the current flowing through it? If the hair dryer is used for 3 minutes, how much energy does it consume?*

Solution:

Given data:

Power of dryer = P = 1875 watt

Voltage = V = 120V

Time = t = 3min = 3 x 60sec = 180sec

Required:

(i) Current = I = ?

(ii) Energy consumed = E = ?

Calculation:

(i) We know that,

$$P = IV \Rightarrow I = \frac{P}{V} \quad ________ (1)$$

Putting the values in equation (1), we get,

$$I = \left(\frac{1875}{120}\right) A = 15.625A = 15.6A \Rightarrow \boxed{I = 15.6A}$$

(ii) We know that,

$$E = P \times t \quad ________ (2)$$

Putting the values of "P", "t" in equation (2), we get,

$$E = (1875 \times 180)J = 337500.0J$$

$$\Rightarrow E = 337.5 \times 10^3 J = 337.5kJ$$

$$\Rightarrow \boxed{E = 337.5kJ}$$

Answers:

(i) $\boxed{\text{Current} = I = 15.6A}$

(ii) $\boxed{\text{Energy} = E = 337.5kJ}$

**Q6: A battery with an emf of 12V is connected to a 545Ω resistor. How much energy is dissipated in the resistor in 65s?**

Solution:

Given data:

Battery emf = V = 12V

Resistance = R = 545Ω

Time = 65sec

Required:

Energy dissipated = E = ?

Calculation:

We know that,

$$E = P \times t \quad \text{________(1)}$$

We also know that,

$$P = \frac{V^2}{R} \quad \text{________(2)}$$

Putting equation (2) in equation (1), we get,

$$E = \frac{V^2}{R} \times t \quad \text{________(3)}$$

Putting the values of "V", "t" and "R" in equation (3), we get,

$$E = \left[\frac{(12)^2}{545} \times 65\right] J = 17.1J = 17J$$

**Energy dissipated = E = 17J** Ans.

**Q7: If the unit of electricity cost 8.11Rs/kWh, what is cost of running two 160W fans and four 100W light bulbs for 6 hours in school?**

Solution:

Given data:

Tariff rate = T.R = 8.11Rs/kWh

Power of two 160W fans = $P_1$ = 160 x 2 = 320W

Power of four 100 watt bulbs

$= P_2 = 100 \times 4 = 400W$

Total power $= P = P_1 + P_2 = (320 + 400)W$

$= 720W = 0{\cdot}272kW$

Time = t = 6 hours

*Required:*

Cost of electricity = C = ?

*Calculation:*

We know that,

Cost of electricity = Energy consumed x tariff rate

$\therefore \quad E = C \times T{\cdot}R$ ____________(1)

We know that,

$E = P \times t$ ______________(2)

Putting equation (2) in equation (1), we get,

$E = P \times t \times T{\cdot}R$ ____________(3)

Putting the values in equation (3), we get,

$C = (0{\cdot}720 \times 6 \times 8{\cdot}11)Rs$

$\therefore \quad \boxed{C = 35{\cdot}0\ Rs}$

$\boxed{\text{Cost of electricity consumed} = C = 35{\cdot}0\ Rs}$ Ans·

OOO

- جب کبھی کسی مسلمان کو کوئی قلبی تکلیف، کوئی جسمانی بیماری، کوئی دُکھ اور غم پہنچتا ہے اور وہ اس پر صبر کرتا ہے تو اس کے نتیجے میں اللہ تعالیٰ اس کی خطاؤں کو معاف کرتا ہے یہاں تک کہ اگر اسے ایک کانٹا چبھ جاتا ہے تو وہ بھی اس کے گناہوں کی معافی کا سبب بنتا ہے۔(حضور اکرم ﷺ)
- آدمی کے جھوٹا ہونے کے لیے یہ کافی ہے کہ جو کچھ بھی سنے بیان کردے۔(مسلم شریف)
- سچا آدمی سچائی کی بدولت اس مرتبہ کو پہنچ جاتا ہے جسے جھوٹا آدمی مکر و حیلہ سے نہیں پا سکتا۔
- بیکار لوگوں کے دلوں میں شیطان فوراً کارخانہ کھول دیتا ہے۔
- احمق جب تک خاموش رہے عقل مند شمار ہوتا ہے۔(حضرت سلیمان علیہ السلام)

CHAPTER

# 15 ELECTRO-MAGNETISM

**Q1: Define and explain electromagnetism.**
برقناطیسیت کی تعریف کریں اور وضاحت کریں۔

*Ans. Electromagnetism [برقناطیسیت]*

*"The study of magnetic field associated with moving charges is known as electromagnetism."*

*Explanation [وضاحت]*

*In electrostatic, we have studied that, there are two types of charges. The same charges repel each other while opposite charges attract each other. These charges create electric field.*

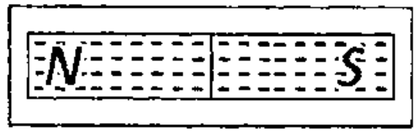
*Similarly, in magnetism, we have study that there are two types of magnetic poles i.e. South pole and North pole. The same poles repel each other while the opposite poles attract each other. These poles creates magnetic field around them.*

*The above discussion shows that the electricity and magnetism are closely related to each other. In 1820, Christian scientist Oersted discovered that an electric current produces a magnetic field in its neighbourhood. In this way, a new branch of physics was born, which is known as electromagnetism.*

**Q2: Write at least four properties of a magnet. (BISE Peshawar 2019)** مقناطیس کی کم از کم چار اہم خصوصیات بیان کریں۔

Ans.

1. A magnet posses two poles i.e., North pole and South pole.




2. A magnet can attract the bits of iron.
3. The North pole of a magnet points in the North direction, while the South pole points in the South direction.
4. The like poles of two magnets repel each other while the opposite poles attract each other.

**Q3: Define magnetic field. How is its intensity and direction be specified?**
مقناطیسی فیلڈ کی تعریف کریں۔ اس کی شدت اور سمت کیسے متعین کی جاتی ہے؟

Ans. "The region around a magnet in which the effect of that magnet can be felt is known as magnetic field."

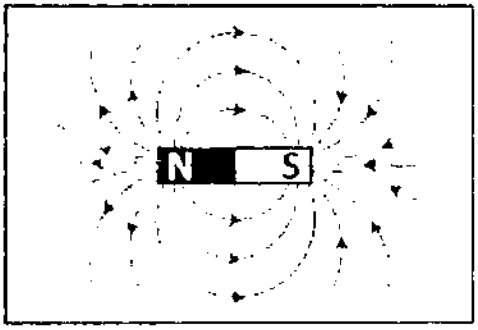
Explanation [وضاحت]

The magnetic field cannot be seen like gravitational field. It can be traced by means of a small test magnet like a compass needle. Its magnitude, intensity and direction at any field point can be determined by magnetic force exerted by the field on a test magnet placed at that point. The magnetic field is represented by lines of force.

**Q4: What do you meant by magnetic lines of force? Represent the field pattern of a bar magnet by lines of force.** مقناطیسی خطوط قوت سے کیا مراد ہے؟اس کی خصوصیات بیان کریں۔

Ans. "The path along which a test magnet can move in a magnetic field is known as magnetic lines of force."

Explanation [وضاحت]

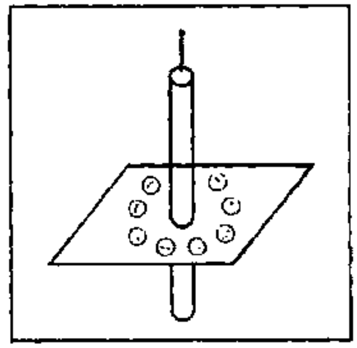



The magnetic lines of force posses the following properties:

1. The magnetic lines of force starts from North pole and end at the South pole of the magnet.
2. The magnetic lines of forces are crowded near the poles, because the intensity of magnetic field is maximum near the poles.
3. The magnetic lines of forces do not intersect each other.
4. The magnetic lines of force can pass through iron easily as compare to air.

**Q5: Describe an experiment to show that the steady current carrying wire produces a magnetic field around it. What is the direction of this magnetic field?**
تجربہ کی مدد سے ایک کرنٹ بردار تار کے گرد مقناطیسی فیلڈ کی موجودگی پر بحث کریں اور اس مقناطیسی فیلڈ کی سمت کیا ہوگی؟(یا) ایک کرنٹ بردار سیدھی تار کے گرد مقناطیسی فیلڈ کا خاکہ پیش کریں۔

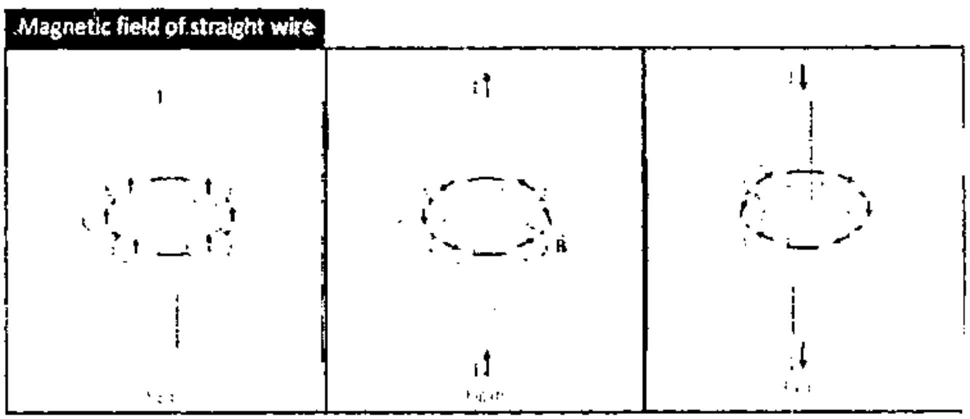
Ans. Consider a long straight wire conductor which is fitted vertically in a piece of card board as shown in the figure.



Let the ends of the wire are connected to the terminals of a battery by means of a switch. Now when the switch is turn ON, then current passes through the wire. Now if we keep some iron filing [لوہے کے ذرات] on the card board, we will see that these filings arrange themselves in the form of concentric circles around the wire.

This shows that the current in the wire give rise to a magnetic field with circular lines of forces.

Direction of Magnetic Field [مقناطیسی فیلڈ کی سمت]




We can detect the presence of magnetic field due to deflection of compass needle.

Case 1: When there is no current in the wire, the compass needle shows no deflection as shown in figure (a).

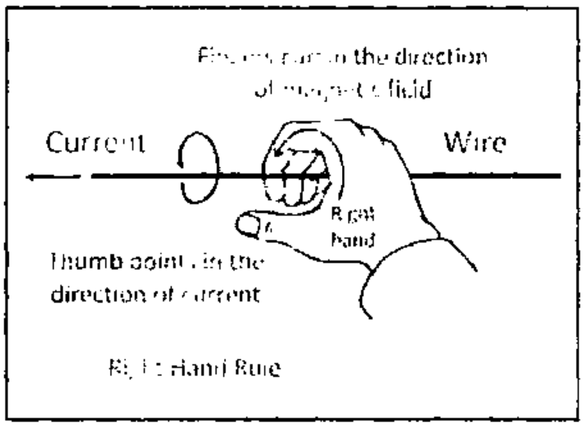
Case 2: When current flows through the wire in upward direction, the magnetic field exist around the conductor in circular form in anti-clockwise direction as shown in figure (b).

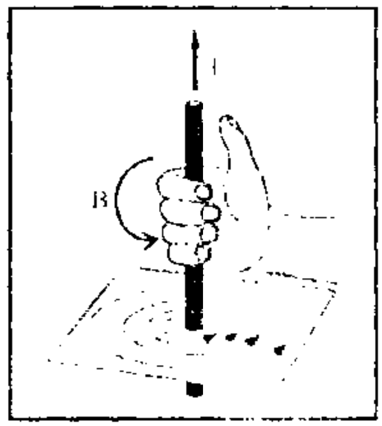
Case 3: When direction of current reverses, the magnetic field also reverses and exists around the conductor in clockwise direction, as shown in figure (c).

**Q6: State and explain the right hand rules with the help of diagram.** شکل کے ذریعے دائیں ہاتھ کے قانون کی وضاحت کریں۔

Ans. Right Hand Rule [دائیں ہاتھ کا قانون]

This rule states that, "if the current carrying wire is grasped by the right hand with the thumb in the direction of current, then the fingers encircle the wire in direction of the field."



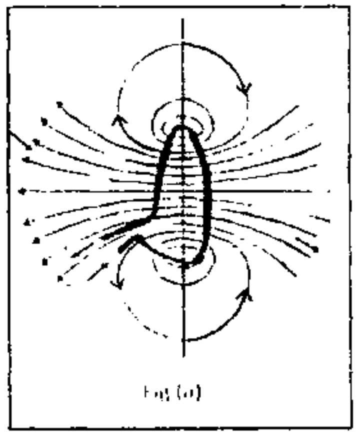



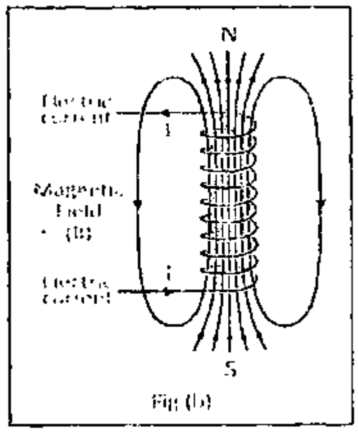

Thus the right hand rule relates the direction of magnetic lines of force around a wire with the direction of current flowing through it.

**Q7: How the magnetic field of wire increases and resembles more like that from a permanent magnet, if the wire is formed in a circular coil?**
ایک سرکلر کرنٹ بردار کوائل کے گرد مقناطیسی فیلڈ کی شدت کو مستقل مقناطیسی فیلڈ کی طرح کس طرح بڑھایا جا سکتا ہے۔ وضاحت کریں۔

Ans. Consider a circular loop of wire as shown in figure.

When current is allowed to pass through this wire, then magnetic field is set up and the wire behaves as a magnet. One face of the wire [coil] behaves as North pole and the other as South pole. The magnetic field in the central region is uniform having parallel and straight lines of forces.






The field becomes non uniform away from the central region. The intensity of the field depends upon the number of turns in the coil. If the number of turns increases, the number of magnetic field line increases, such that the field resembles to that of a permanent magnet. The side of coil from which the magnetic field lines originate behaves like South pole and the other side of the coil behave like a North pole as shown in the figure (b). Thus the strength of magnetic field depends upon the number of turns in the coil.

**Determination of direction of magnetic field in case of spring shaped coil**

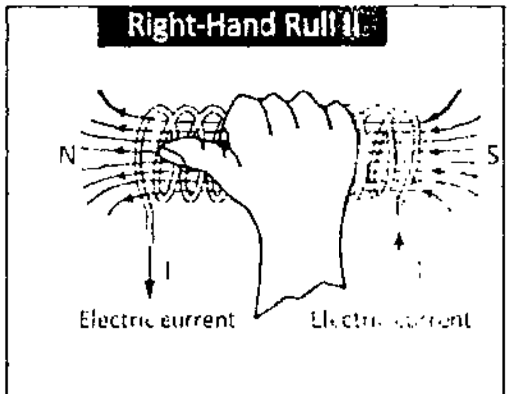
[سپرنگ کی شکل میں کرنٹ بردار تار کے گرد مقناطیسی فیلڈ کی سمت کا تعین کرنا]

In case of spring shaped coil, the direction of mag-

*netic field can be determined by right hand rule-II which is given below:*

*Right Hand Rule-II*

*Right hand rule-II for a solenoid:* *Curl the fingers in the direction of current around the coil or solenoid and the extended thumb will point in the direction of North pole of a magnet. This rule is for direction of conventional current or flow of positive charges. For electronic current flow, the same rule is applied but with left hand.*



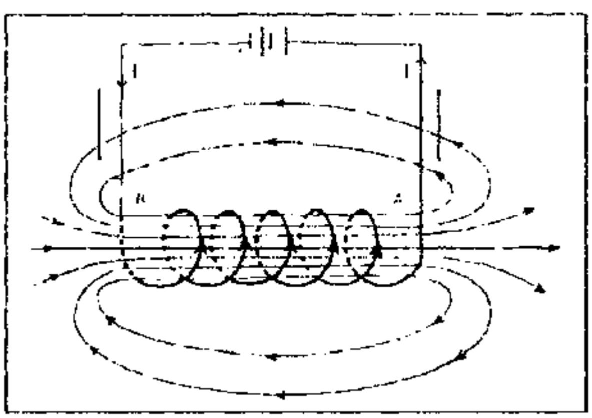

The right-hand rule (II) for a soleniod

> *Q8: Discuss the magnetic field due to current carrying solenoid. Discuss the uses of solenoid.*
> کرنٹ بردار سالینائیڈ کی مقناطیسی فیلڈ کی وضاحت کریں اور اس کے فوائد بیان کریں۔

*Ans. Solenoid [سالینائیڈ]*

*A solenoid is a wire which is wound in such a way, that it acquires a spring shape, as shown in the figure.*

*When current passes through the solenoid, a magnetic field is set up and the solenoid behaves as a magnet. Its one end acts as North*

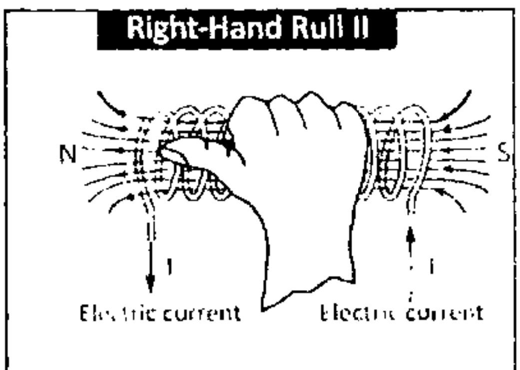


pole and the other acts as South pole.

The magnetic field inside the solenoid is very strong and uniform because the lines of forces are closer and parallel to each other. The magnetic field outside the solenoid is extremely very weak because the lines of forces becomes far away from each other and becomes curved as shown in the figure.

The intensity "B" of the field depends upon the current flowing through the solenoid. The intensity increases with increase in current and vice versa. The intensity also depends upon the number of turns of solenoid. Greater the number of turns of solenoid, greater will be intensity of the field and vice versa.

The polarity of the magnet depends upon the direction of current. It can be determined by the right hand rule. For this purpose, the solenoid should be grasp in right hand in such a way that the fingers remains in the direction of current. Under such conditions, the thumb will indicate towards the North pole of solenoid.



The right-hand rule (II) for a soleniod

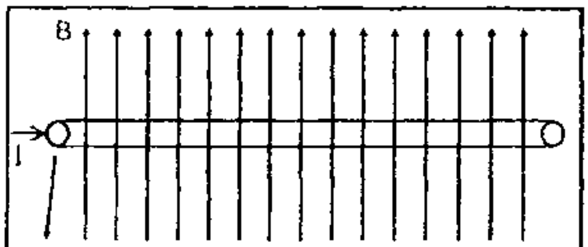
Uses of Solenoid

1. Using solenoid, we can determine the strength of magnetic field.
2. Using solenoid, we can determine the amount of current in the coil.

3. Using solenoid, we can determine the South and North pole of the field.

**Q9: (a) Discuss the magnetic force on a current carrying conductor. (b) State Fleming left hand rule for determining the direction of force acting on current carrying conductor.**
کرنٹ بردار تار پر لگنے والے مقناطیسی قوت پر بحث کریں اور فلیمنگ کے بائیں ہاتھ کے قانون کے مطابق مقناطیسی قوت کی سمت معلوم کریں۔
(BISE Bannu, Kohat 2019)

Ans. (a) We know that the current flows through a conductor [wire] due to motion of free electrons in the conductor. Now if we place such a conductor in a uniform magnetic field of strength "B", then the electrons experience certain magnetic force "F". As a result, the conductor faces the magnetic force which is perpendicular to the conductor. The magnitude of this force depends upon the following factors:



Current carrying conductor

1. The force is proportional to the intensity of magnetic field "B". i.e.,
$F \propto F$ ________(1)
2. The force is proportional to the amount of current "I" in the conductor. i.e.,
$F \propto I$ ________(2)
3. The force is proportional to the length of the conductor. i.e.,

$F \propto L$ ____________(3)

Combining relation (1), (2) and (3), we get,

$F \propto BIL$

$\therefore F = \text{Constant} \cdot BIL$ ____________(4)

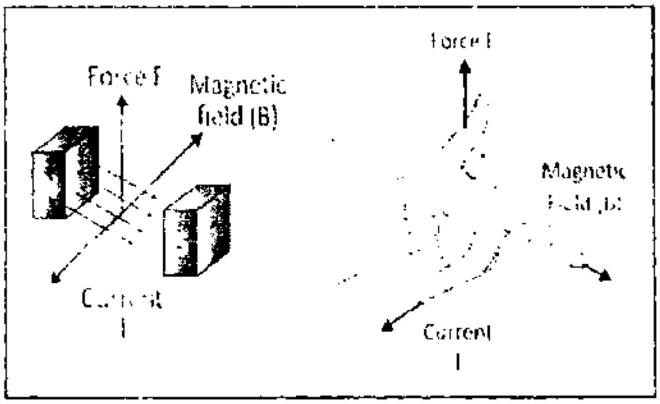
Put constant = 1, so equation (4) >

$\boxed{F = BIL}$ ____________(5)

Equation (5) represents the magnitude of magnetic force acting on a current carrying conductor.

(b) Fleming Left Hand Rule

Fleming's left hand rule can also be used to represent the direction of force. The thumb and the first two fingers of the left hand are set at right angles



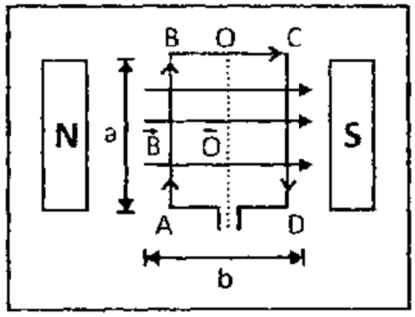

to each other. With the first finger pointing in the direction of the field, the second finger pointing in the direction of current, the thumb will give the direction of force.

**Q10: Discuss how torque is produced on a current carrying loop [conductor]?**

مقناطیسی فیلڈ میں کرنٹ بردار کوائل پر ٹارک کی وضاحت کریں۔

Ans. Consider a rectangular coil "ABCD" which is placed in a uniform magnetic field of strength "B" as shown in the figure.

Now if current is allowed to flow through this coil,




then magnetic force on sides "BC" and "AD" will be zero because these sides are parallel to the field. While on sides "AB" and "CD" there must be some force in opposite direction, because these sides are perpendicular to magnetic field. Due to these anti-parallel forces, the coil begins to rotate horizontally. As a result, torque is produced which acts on the coil.

Now we know that, torque is given by,

$\tau = r \times F$ ________(1)

Also $F = BIL$ ________(2)

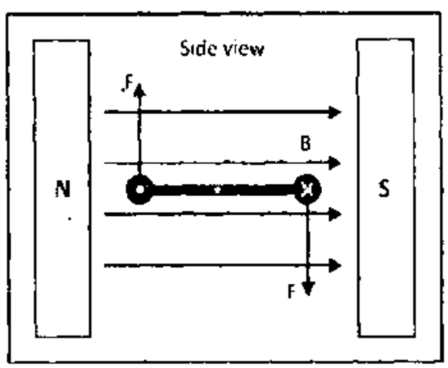
Putting equation (2) in equation (1),

$\tau = r \times BIL$ ________(3)

Here we have, $L = a$ = length of coil and $r = b$= width of coil, so equation (3) becomes

$\tau = bBIa = BI(ba)$

$\Rightarrow \quad \tau = BI(ba)$ ______(4)




Here $ba$ = Area of coil = $A$

So equation (4) becomes,

$\boxed{\tau = BIA}$ ________(1)

Equation (5) represents the magnitude of torque on coil for a single turn. If there are N-turns, then equation (5) can be written as,

$\boxed{\tau = NBIA}$ __________(6)

Equation (6) represents the magnitude of torque when the coil consists of N-turns.

**Q11: Describe the phenomenon of electromagnetic induction. List the factors effecting electromagnetic induction.**

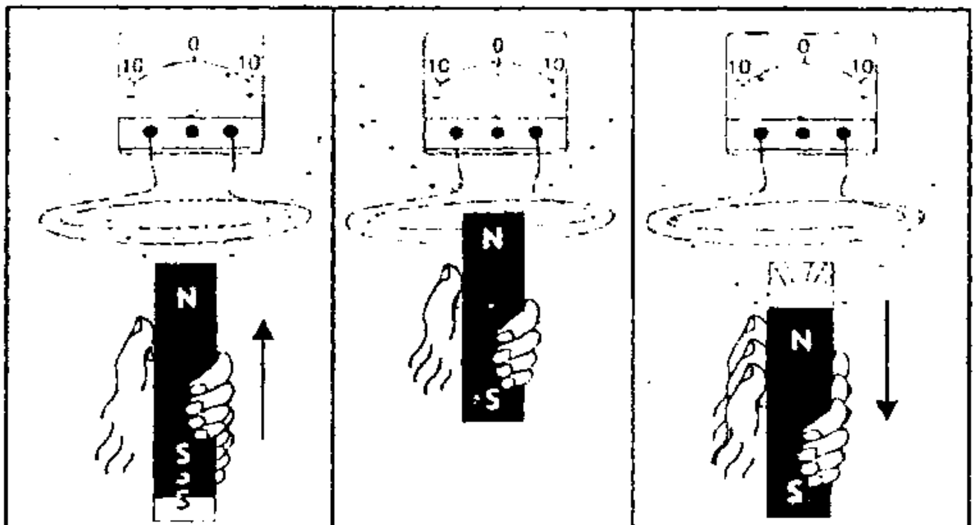
برقناطیسی آمالہ کی وضاحت کریں۔اس پر اثر انداز ہونے والے عوامل بیان کریں۔

Ans. Definition: (BISE Pesh, Kohat, Swat, Mardan, Bannu 2019)

"The phenomenon in which an induced emf is produced in a coil due to change in magnetic flux is called electromagnetic induction."

Explanation [وضاحت]

Consider a coil of wire connected to a galvanometer as shown in the figure. When the magnet is stationary [even inside the coil], the galvanometer shows no current as shown in the figure (a). But when we move the magnet either towards or away from the coil, the galvanometer shows current in the circuit. If we keep the magnet stationary and move the coil, we again detect a current during the motion. We call this an induced current and the corresponding emf required to create this current is called an induced emf. Whenever we have a changing magnetic field, an emf is induced. If the circuit is completed, the induced emf will cause an induced current to flow. It should be noted that when magnet and coil are moved towards each other, the galvanometer shows deflection in one direction as shown in the figure (b).




When the magnet and the coil are moved away from each other, the galvanometer shows deflection in the other direction as shown in figure (c). When both are fixed, no such deflection occurs, as shown in the figure (a).

Factors affecting magnitude of induced emf

The magnitude of induced emf depends upon the following factors:

1. When a double loop of wire is used, the deflection on the galvanometer is twice as large as before. A triple loop induces three times the emf and so on. This shows that "the emf is proportional to the number of turns in a coil."
2. The faster the wire is moved, the larger the deflection on the galvanometer. This indicates that the speed at which the conductor moves through the magnetic field also determines the magnitude of induced emf.

3. The longer the length of the conductor in the magnetic field, the greater is the induced emf.
4. The larger the magnetic field, the greater the emf induced.

**Q12: Explain the direction of induced emf and show its relation to conservation of energy.**
انڈیوسڈ ای ایم ایف کی سمت کی وضاحت کریں اور توانائی کی بقاء سے اس کا تعلق واضح کریں۔

Ans. The direction of induced emf can be determined by using Lenz's law. This law states that the induced emf always opposes the cause due to which it is produced.

Explanation [وضاحت]

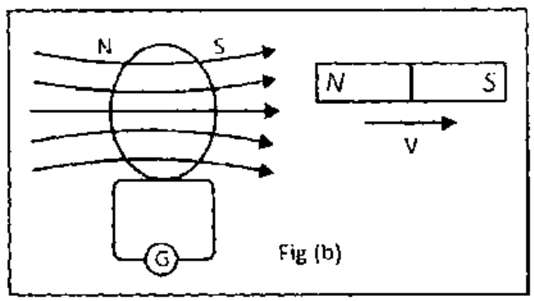


Fig (b)

Let a bar magnet with N-pole is allowed to push with velocity "V" towards a coil connected to galvanometer as shown in the figure (a). The magnetic field lines originated from N - poles of the magnet passes through the coil as shown in the figure. When these lines pass through the coil, the right side of the coil acts as N-pole and left side acts as S - pole. So when we push the bar magnet towards the coil, it experience an opposing force due to repulsion between N - pole of bar magnet and N - pole of the coil. So work must be done against this opposing force. When magnetic lines passes through the coil, magnetic flux changes and as a result induced current is produced due to which the

galvanometer shows deflection.

Similarly, if we push the bar magnet away from the coil, the process is reversed. The left side of coil behaves as N – pole and right side behaves as S – pole as shown in figure (b). Thus attraction exists between S – pole of coil and N – pole of bar magnet. Thus again work must be done against this attractive force between opposite poles. This shows that the induced emf always opposes the cause due to which it is produced. It is known as Lenz's law.

**Conservation of Energy**

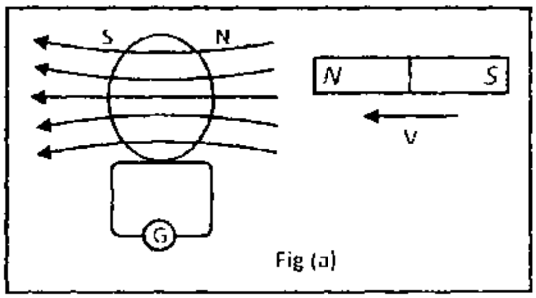


Fig (a)

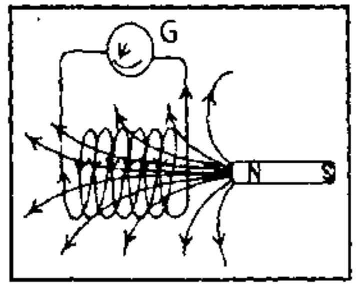
As the induced emf opposes the motion of the bar magnet, so work must be done against such opposing agent. This work done is stored in the form of electrical energy in the cuit. Thus energy is conserved in this phenomenon.

**Q13: State and explain Faraday's law of electromagnetic induction.**

Ans. **Statement:** (BISE Malakand 2019)

This law states that, "whenever the magnetic flux linked with a conductor changes, then an induced emf is produced in the coil whose value is directly proportional to the rate of change of magnetic flux."

*Explanation [وضاحت]*




*Consider a circuit which a galvanometer is connected to the end of a coil, as shown in the figure. Now if a bar magnet is brought closer to the coil, then the number of magnetic lines of forces passing through the coil increases. As a result, the magnetic flux changes. Due to change in magnetic flux, an induced emf is produced in the coil. Due to induced emf, an induced current is produced due to which the galvanometer shows some deflection.*

*Faradays found that, the value of induced emf is directly proportional to the rate of change of magnetic flux. i.e.,*

$$\varepsilon \propto \frac{\Delta\phi}{\Delta t} \qquad \varepsilon = constt \cdot \frac{\Delta\phi}{\Delta t} \quad \text{______(1)}$$

*Put constant = 1, then equation (1) becomes*

$$\boxed{\varepsilon = -\frac{\Delta\phi}{\Delta t}} \quad \text{__________(2)}$$

*Equation (2) represents the mathematical form of Faradays law of electromagnetic induction. The negative sign shows that the induced emf always opposes the cause due to which it is produced. If the coil consists of N - number of turns, then equation (2) can be written as,*

$$\boxed{\varepsilon = -N\frac{\Delta\phi}{\Delta t}} \quad \text{_________(3)}$$

*Equation (3) represents the mathematical form of Faraday's law of electromagnetic induction, when*

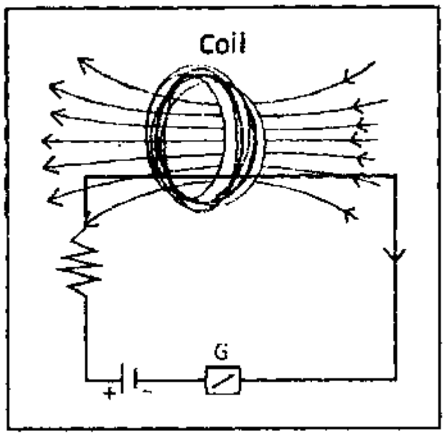
the coil consists of N – number of turns.

**Q14: Define and explain self induction.**
خود آمالہ کی تعریف اور وضاحت کریں۔

Ans. Self Induction:

It is the phenomenon in which an induced emf is produced in a coil due to its own changing current.

Explanation [وضاحت]




Consider a coil which is connected to rheostat and a battery, as shown in the figure. Now if we vary the resistance of rheostat, then current in the coil changes. Due to change in current, the magnetic flux also changes. Due to change in magnetic flux, an induced emf is produced in the coil. The magnitude of induced emf is directly proportional to the rate of change of current in the coil. i.e.,

$$\varepsilon \propto \frac{\Delta I}{\Delta t}$$

$$\Rightarrow \quad \varepsilon = \text{constant} \ \frac{\Delta I}{\Delta t}$$

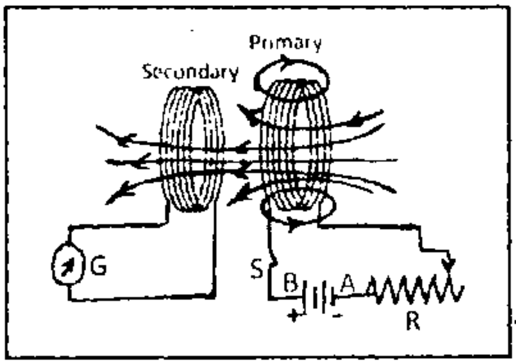
$$\Rightarrow \quad \boxed{\varepsilon = -L \, \Delta I / \Delta t} \quad \text{———} (1)$$

In equation (1), "L" is constant and is known as self induction of the coil. The negative sign shows that the induced emf always opposes the cause due to which it is produced.

**Q15: Describe the phenomenon of mutual induction.** باہمی آمالہ کی وضاحت کریں۔

Ans. **Mutual Induction [باہمی آمالہ]**

At is the phenomenon in which an induced emf is produced in one coil due to change in current in another coil.




**Explanation [وضاحت]**

Consider two coils such that one is called primary coil and the other is known as secondary coil.

The primary coil is connected to a battery while the secondary coil has no source of emf. Let the two coils are placed side by side closer to each other as shown in the figure.

When the switch "S" is open, then no magnetic field lines will pass through any of the coils. When the switch "S" is closed, a magnetic field is set up around the primary coil due to the flow of current in the primary coil. Due to current in primary coil, magnetic flux is produced which is linked with the secondary coil.

Now if the current in the primary is allowed to change with the help of rheostat "R", then the magnetic flux linked with the secondary coil also changes. As a result, an induced emf is produced in the secondary coil. Such phenomenon is known as mutual induction.

*Mathematical form:*

If "$\varepsilon_s$" represents the emf in secondary coil and "$\frac{\Delta I_p}{\Delta t}$" represents the rate of change of current in the primary coil, then, $\varepsilon_s \propto \frac{\Delta I_p}{\Delta t}$

$$\Rightarrow \quad \varepsilon_s = \text{constant}\ \frac{\Delta I_p}{\Delta t} \Rightarrow \boxed{\varepsilon_s = -M\frac{\Delta I_p}{\Delta t}} ______(1)$$

In equation (1), "M" is constant and is known as mutual inductance of the coil. The negative sign shows that the induced emf opposes the cause due to which it is produced.

*Unit of Mutual Inductance*

As $\varepsilon_s = M\frac{\Delta I_p}{\Delta t}$

$$\Rightarrow \quad M = \frac{\varepsilon_s}{\left(\frac{\Delta I_p}{\Delta t}\right)} ______(2)$$

If $\frac{\Delta I_p}{\Delta t} = \frac{1amp}{sec}$ and $\varepsilon_s = 1\,volt$, then equation (2) becomes

$$M = \frac{1volt}{(1amp\ /\ sec)} = 1\ \text{Henry}$$

So the unit of mutual inductance is Henry.

*Definition of Henry:*

The mutual inductance is said to be one Henry if the current in primary coil changes at the rate of one ampere per second and causes an induced emf of one volt across the secondary coil.

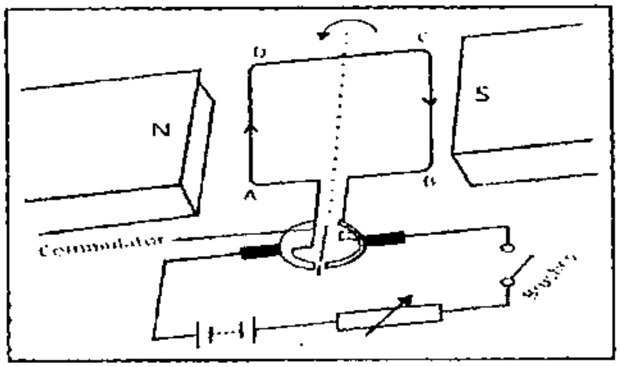
**Q16: Explain the working of D·C motor·**

ڈی۔سی موٹر کی وضاحت کریں۔

Ans· D·C Motor: (BISE Kohat 2019)

It is a device which converts electrical energy into mechanical energy·

**Construction:**




It consists of a coil which is called armature· The armature is connected to commutator· The commutator receives current from the brushes which are in contact with them·

**Working:**

When current reaches the armature coil, it begins to rotate· The rotation of armature coil produces mechanical power· In this way, a D·C motor converts electrical energy into mechanical energy·

**Uses of D·C Motors:**

The electric motors are used in electric fans, water pump, washing machines, telephones, T·V, tape record and radar etc·

**Q17: Sketch and describe the construction and working of A·C generator·**

اے۔سی جنریٹر کی ساخت اور کارگزاری بیان کریں۔ شکل سے واضح کریں۔

Ans· Definition: (BISE Kohat 2019)

It is a device which converts mechanical energy into electrical energy·

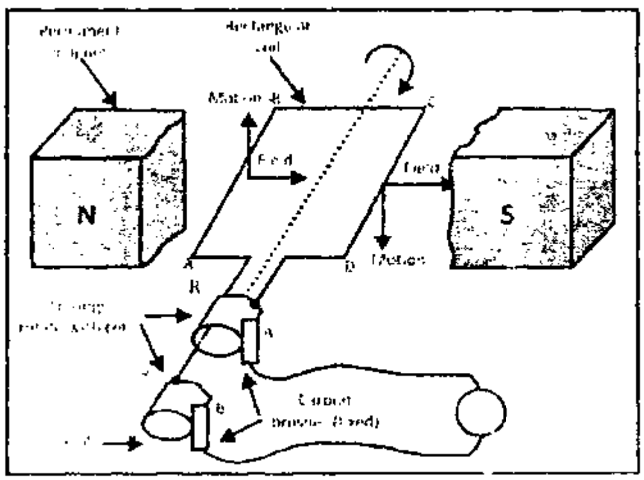
*Principle of Working:*

*Its principle is based on the principle of electro-magnetic induction.*

*Construction [ساخت]:*

*It consists of a rectangular coil having number of turns "N". The coil is wounded on an iron core. This combination of iron core and coil is known as armature. The terminals of the coil are connected to rings "R" and "R′". The brushes "b" and "b′" connect the rings to the external circuit.*

*Working [کارگزاری]:*




*During operation, the armature coil rotates about its axis. When the coil becomes perpendicular to magnetic field, then the magnetic flux becomes maximum and when the coil becomes parallel to the magnetic field, then the magnetic flux becomes zero.*

*In this way, the magnetic flux changes alternatively and thus an induced emf is produce in the circuit which result in the production of electricity.*

*Uses of A.C Generator:*

*A.C generators are used in power stations like Malakand, Warsak, Tarbela etc, where it convert the*

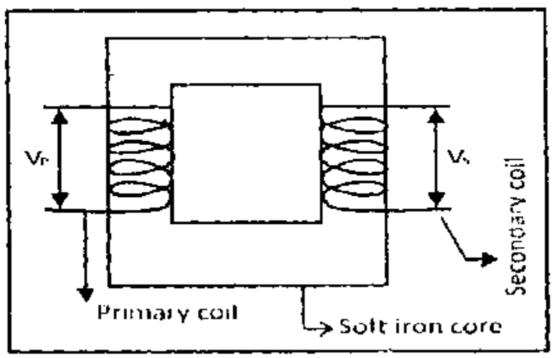
K·E of water falls into electrical energy· They are also used to convert the chemical energy of petrol and diesel into electrical energy·

**Q18: What are transformers? Explain its construction, principle of working· Also describe the purpose of transformers in A·C circuit·**
ٹرانسفارمر کیا ہوتا ہے؟ اس کی ساخت اور کام کرنے کا اصول بیان کریں۔ اے۔ سی سرکٹ میں ٹرانسفارمر کے استعمال کا مقصد بیان کریں۔

Ans· Transformer [ٹرانسفارمر]:

It is a device which can increase or decrease the value of an alternating voltage·

Construction:




It consist of laminated soft iron core upon which two coils are wounded as shown in the figure· One coil is known as primary coil and the other is known as secondary coil·

Principle:

Its principle is based on the phenomenon of mutual induction i·e·, a change in current in one coil produces an induced emf in the other coil·

Working:

When an alternating voltage is applied across the primary coil, then an alternating current flows in the primary coil· This current produces a continuously changing magnetic flux which causes an induced emf in the secondary coil due to the phenomenon of mutual

induction.

The magnitude of output voltage across the secondary coil depends upon the ratio between numbers of turns in the two coils.

Let "$V_p$" represents the voltage across the primary coil and "$V_s$" represents the voltage across the secondary coil. Let "$N_p$" represents the number of turns in the primary coil and "$N_s$" represents the number of turns in the secondary coil. Then the relation between them is given by,

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad \text{———— (1)}$$

**Step-up Transformer:**

If $N_s > N_p$, then $V_s > V_p$ the transformer in such a case is called step-up transformer.

**Step-down Transformer:**

If $N_s < N_p$, then $V_s <\ _p$ the transformer in such a case is known as step-down transformer.

**Purposes of transformers in A.C circuits (OR) Uses of transformers:**

1. It is used for increasing or decreasing alternating voltage. The power companies use transformers to step-up the voltage to high-level. It reduces the power losses in A.C circuits. If power plant produces a voltage of 13000 volts, then such voltage can be raised to 500000 volts with the help of step-up transformers. Similarly, for domestic use, the high voltage can be reduced to 240 volts by

using step-down transformers.

2. It is used in cheaper transmission of electrical energy from one place to another.
3. It is used in design of circuits for communication in radio, television, radar and other devices.

## Solution of Examples, Assignments

**Example 1:** Can the magnetic force on a current carrying wire be large enough to suspend the wire against gravity? Consider a wire having mass of $6.24 \times 10^{-4}$kg and length 3.5cm place perpendicular to a 2.4T magnetic field. How large a current must the wire carry in order to be suspended against gravity?

Solution:

Given data: Mass = $m = 6.24 \times 10^{-4}$kg

Length = $L$ = 3.5cm = 0.035m

Magnetic field = $B$ = 2.4T

Acceleration due to gravity = $g$ = 9.8m/s$^2$

Required: Current = $I$ = ?

Calculation: In order to suspend a wire against gravity, the magnetic force on a wire must balance its weight $W$, such that

$$F_m = W \Rightarrow BIL = mg$$

$$\Rightarrow \quad I = \frac{mg}{BL} \quad ________(1)$$

Putting the values in equation (1), we get,

$$\Rightarrow \quad I = \frac{mg}{BL} = \left(\frac{6\cdot24 \times 10^{-4} \times 9\cdot8}{2\cdot4 \times 0\cdot035}\right)A \qquad \boxed{\begin{array}{l} F_m = BIL \\ w = mg \end{array}}$$

$\boxed{I = 0\cdot073A}$ or $\boxed{I = 73mA}$ Ans·

> *Assignment 1: A wire carrying a steady (dc) 30A current has a length of 0·12m between the pole faces a magnet· The wire is at an angle θ =60° to the field· The magnetic field is approximately uniform at 0·90T· Determine the magnitude of the force on the wire·*

*Solution:*

*Given data:* Current = $I$ = 30A

Length of wire = $L$ = 0·12m

Angle = $\theta$ = 60°

Strength of magnetic field = $B$ = 0·90T

*Required:* Magnitude of magnetic force = $F_m$ = ?

*Calculation:* We know that,

$F_m = BIL \sin\theta$ ___________(1)

Putting the values in equation (i), we get,

$F_m = (0\cdot90 \times 30 \times 0\cdot12 \times \sin 60°)N = 2\cdot8N$

$\boxed{F_m = 2\cdot8N}$ Ans·

> *Example 2: If the mutual inductance of two coils is 3·5mH and the current through primary coil changes from 0A to 10A in 0·03s, how much emf is induced in the secondary coil?*

*Solution:*

*Given data:*

Mutual inductance = $M$ = 3·5mH

$= 3\cdot5 \times 10^{-3}H$

Initial current = $I_i$ = 0A

Final current = $I_f$ = 10A

Time taken for change = $\Delta t$ = 0·03s

Required: Induced emf in secondary = $\varepsilon_s$ = ?

Calculation: The emf induced in the secondary coil is given by the equation

$$\varepsilon_s = -M\left(\frac{\Delta I}{\Delta t}\right) = -M\left(\frac{I_f - I_i}{\Delta t}\right) \quad \text{———— (1)}$$

Putting values in equation (1), we get,

$$\Rightarrow \quad \varepsilon_s = -3{\cdot}5 \times 10^{-3}\left[\frac{10 - 0}{0{\cdot}03}\right] \text{volt}$$

$$\Rightarrow \quad \varepsilon_s = -1166{\cdot}6 \times 10^{-3} \text{volt}$$

$$= -1{\cdot}1666 \text{ volt} = -1{\cdot}17V$$

$$\boxed{\varepsilon_s = -1{\cdot}17V} \quad \text{Ans·}$$

Assignment 2: If the current through the primary coil changes from 0A to 10A in 0·02s, such that the induced emf is 4·3V· What is the mutual inductance?

Solution:

Given data: Initial current = $I_i$ = 0A

Final current = $I_f$ = 10A

Time = $\Delta t$ = 0·02sec

Induced emf = $\varepsilon_s$ = 4·3V

Required: Mutual inductance = M = ?

Calculation: We know that,

$$\varepsilon_s = -M\frac{\Delta I}{\Delta t} = -M\left(\frac{I_f - I_i}{\Delta t}\right)$$

$$\Rightarrow \quad 4\cdot3V = -M\left(\frac{10-0}{0\cdot02}\right)\frac{A}{sec}$$

$$\Rightarrow \quad 4\cdot3V = -M \times 500\,\frac{A}{sec}$$

$$\Rightarrow \quad M = \left(-\frac{4\cdot3}{500}\right)Henry = 8\cdot6 \times 10^{-3}H = -8\cdot6mH$$

$\boxed{M = -8\cdot6mH}$ Ans.

**Example 3: A portable x-ray unit has a step-up transformer, the 200V input of which is transformed to the 100kV output needed by the x-ray tube. The primary has 50 loops, what is the number of loops in the secondary?**

Solution:

Given data: Primary voltage = $V_p$ = 220V

Secondary voltage = $Vs$ = 100kV

$= 100 \times 10^3V = 10^5V$

Number of turns in the primary = $N_p$ = 50

Required:

Number of turns in the secondary = $N_s$ = ?

Calculation: We know that,

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow N_s = \frac{V_sN_p}{V_p} \qquad \text{———(1)}$$

Putting values in equation (1), we get,

$$\Rightarrow \quad N_s = \frac{10^5 \times 50}{220} = 0\cdot227 \times 10^5 \text{ turns}$$

$$= 2\cdot27 \times 10^4 \text{ turns}$$

$\boxed{N_s = 2\cdot27 \times 10^4 \text{ turns}}$ Ans.

> *Assignment 3: A step-up transformer has a primary coil consisting of 200 turns and a se●ondary coil consisting of 300C turns. The primary coil is supplied with an effective AC voltage of 90.0V. What is the voltage in the secondary circuit?*

*Solution:*

*Given data:*

Number in turns in primary coil = $N_p$ = 200

Number of turns in secondary coil = $N_s$ = 3000

Voltage across the primary = $V_p$ = 90V

*Required:* Voltage across the secondary coil = $V_s$ = ?

*Calculation:* We know that,

$$\frac{N_s}{N_p} - \frac{V_s}{V_p} \Rightarrow V_s = \frac{N_s V_p}{N_p} \quad ______(1)$$

Putting values in equation (1), we get,

$$\Rightarrow \quad V_s = \left(\frac{3000 \times 90}{200}\right) V$$

$$\boxed{V_s = 1350V} \quad \text{Ans.}$$

- زندگی کا مقصد مسرت نہیں بلکہ تکمیل انسانیت ہے۔
- احسان کا بدلہ نہ چاہنا احسان ہے۔
- تم میں بہتر وہ لوگ ہیں جو اخلاق کے اچھے ہیں۔
- صرف اسلام ایک ایسا دین ہے جو زندگی کے ہر پہلو میں مدد کرتا ہے۔
- اسلام ایک مکمل ضابطہ حیات ہے۔

## Exercise

**Q1: Choose the correct answer.**

1. A current carrying wire in which current flow in northward direction is deflected towards the east by a magnetic force. The direction of the magnetic field is.......
   a. Straight up✓ b. Straight down
   c. South d. West

**Solution:**

Use right hand rule

2. Which derived unit is equivalent to tesla T?
   a. Nm/A b. NA/m
   c. N/Am✓ d. Am/N

**Solution:**

$$F = BIL \Rightarrow B = \frac{F}{IL} = \frac{N}{A \cdot m}$$

3. The unit of inductance, the Henry, is equivalent to:
   a. Vs/A✓ b VA/m
   c. As/V d. V/A

**Solution:**

$$\varepsilon = L\frac{\Delta I}{\Delta t} \Rightarrow L = \frac{\varepsilon \cdot \Delta t}{\Delta I} = \frac{volt \cdot sec}{ampere} = \frac{V \cdot s}{A}$$

4. When the speed at which a magnet is moved through a coil is increased, the induced voltage?
   a. Increases✓ b. Remain the same
   c. Decreases d. Goes to 0

**Solution:**

$$\varepsilon = BVL \Rightarrow \varepsilon \propto V$$

So when speed increases, e.m.f also increases.

5. Slip rings are part of:
   a. DC motor b. AC generator✓
   c. Transformer d. Magnet
6. A transformer is used for:
   a. both DC and AC b. AC voltages✓
   c. DC voltages d. Farming

Solution:

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow \text{turns ratio is voltage.}$$

7. A step-up transformer has a primary winding with 500 turns and a secondary winding with 250 turns, the turns ratio is:
   a. Power b. Energy c. Voltage✓ d. Current
8. A certain transformer has a primary winding with 500 turns and a secondary winding with 250 turns. The turns ratio is:
   a. 0.5✓ b. 2 c. 250 d. 750

$$N_p = 500,\ N_s = 250 \Rightarrow \frac{N_s}{N_p} = \frac{250}{500} = \frac{1}{2} = 0.5$$

9. If the turn ratio is 5, the secondary voltage is greater then the primary voltage by a factor of:
   a. 0.2 b. 0.5✓ c. 2.5 d. 5

$$\frac{N_s}{N_p} = 5,\ As\ \frac{V_s}{V_p} = \frac{N_s}{N_p} = 5 \Rightarrow \frac{V_s}{V_p} = 5$$

$$\Rightarrow \boxed{V_s = 5V_p}$$

## Conceptual Questions

**Q1: Differentiate between electric and magnetic fields.**

Ans.

| Electric Field | Magnetic Field |
|---|---|
| 1. Source of electric field is electric charge. | 1. Source of magnetic field are moving charges. |
| 2. Electric field lines are not continuous. | 2. Magnetic field lines are continuous and form closed loops |
| 3. Electric field can change both the magnitude and direction of a charged particle. | 3. Magnetic field can change the direction of a charged particle only. |
| 4. The SI unit of electric field strength is $\frac{Newton}{Coulomb}$. | 4. The SI unit of magnetic field strength is tesla. |

**Q2: Can an electron at rest be set into motion with a magnetic field?**

Ans. No, an electron at rest cannot be set into motion with a magnetic field.

Reasons and Explanation:

We know that the magnitude of magnetic force acting on a charged particle [electron] is given by,

$$F_{mag} = qVB \quad ________(1)$$

Equation (1) shows that the magnetic force depends upon the amount of charge on electron, velocity of electron and strength of magnetic field. Now when the electron is at rest, then we put $V = 0$, so equation (1) becomes,

$$F_{mag} = q \times 0 \times B = 0 \Rightarrow \boxed{F_{mag} = 0} \quad ______(2)$$

Equation (2) shows that when electron is at rest, then it will experience no magnetic force. Thus an electron at rest in magnetic field cannot be set into motion.

**Q3: Which is more likely to show deflection in compass needle, AC current or DC current? Explain.**

Ans. The compass needle shows more deflection in case of direct current (DC).

Reasons and Explanation:

The AC current in the first half cycle is positive where in the next half cycle is negative. These positive and negative half cycles changes very fastly. Therefore when the compass needle is placed close to wire carry AC, its needle will oscillate. But the DC current is uni-directional. When the compass needle is placed near wire carrying DC, it will deflect compass needle along direction of magnetic field of current and keep its deflection as long as the DC flow in the wire. Thus the compass needle will show more deflection in case of direct current (DC).

**Q4: A constant magnetic field is applied to a current carrying conductor. What angle should the wire make with the field for the force to be (a) maximum, (b) minimum?**

Ans. For maximum force, the angle should be $90^o$ and for minimum force, the angle should be $0^o$.

Reasons and Explanation:

We know that the magnetic force on a current car-

rying conductor is given by,

$F = BIL\sin\theta$ ____________(1)

*Condition for minimum force:*

Equation shows that magnetic force on the conductor will be minimum or zero, if $\theta = 0^\circ$ i.e.

$F_{min} = BIL\sin 0^\circ$ $\quad [\sin 0^\circ = 0]$

$\Rightarrow F_{min} = BIL \times 0$

$\Rightarrow \boxed{F_{min} = 0}$

*Condition for maximum force:*

While the force will be maximum if $\theta = 90^\circ$ i.e.

$F_{max} = BIL\sin 90^\circ$ $\quad [\sin 90^\circ = 1]$

$\Rightarrow F_{max} = BIL \times 1$

$\Rightarrow \boxed{F_{max} = BIL}$

**Q5: Why does a compass needle points North?**

Ans. A compass needle always points North.

*Reasons and Explanation:*

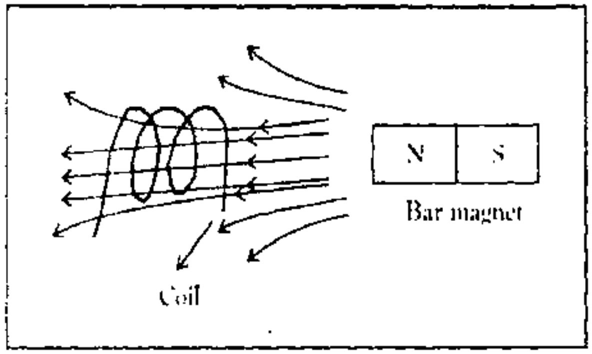
We know that the earth core contain a conducting liquid. When this conducting liquid spins along with the earth, it creates electric field. The electric field produce magnetic field due to which the earth behaves like a magnet. The North Pole of the earth magnet is towards the geographical South while its South Pole is at the geographical North. When the compass magnetic needle is placed in the earth's magnetic field, its South Pole attracts the North Pole of the compass needle, due to which the compass needle points the North.

**Q6: How can a magnetic field be used to generate electric current?**

Ans. We can generate electric current by using a magnetic field. It is because of electromagnetic induction.

Reasons and Explanation:

We know that every changing electric field produce magnetic field and every changing magnetic field produce electric field.




Consider a coil is placed near a bar magnet as shown in the figure. The magnetic field lines originate from North Pole and passes through the coil. The number of magnetic field lines passing through certain area of the coil is called magnetic flux. Now if we move the bar magnet towards the coil or coil towards the bar magnet, then magnetic flux linked with the coil changes. According to Faraday's law of electromagnetic induction, changing magnetic flux causes induced e.m.f in the coil. The induced e.m.f produced induced current in the coil. Thus we can generate electric current by using magnetic field.

**Q7: What would happen if we use a slip ring to drive a DC motor?**

Ans. If we use a slip ring to drive a DC motor, then the coil will oscillate and will not rotate.

*Reasons and Explanation:*

*In DC motors split rings are used for the continuous rotation of the coil in magnetic field. The split rings change the direction of the current in the coil at proper time and as a result the coil rotates continuously.*

*Now if the ends of the coil are connected to slip rings instead of split rings, then the direction of current cannot be changed after half rotation. As a result the coil will oscillate back and forth and will not rotate. Slip rings are generally used in AC motors and AC generators.*

***Q8: The primary coil of a transformer is connected to a DC battery. Is there an e.m.f induced in the secondary coil? Why?***

*Ans. If the primary coil of a transformer is connected to a DC battery, then no e.m.f will be induced in the secondary coil.*

*Reasons and Explanation:*

*Transformers work on the principle of mutual induction. That is a changing magnetic flux linked with primary coil causes an induced e.m.f in the secondary coil.*

*Now if the primary coil of a transformer is connected to DC battery, it would not produce induced e.m.f in the secondary coil. It is because the magnitude and direction of DC does not change. As a result, there will be no change in magnetic flux. When there is no change in magnetic flux, then no e.m.f will be induced in the secondary coil.*

## Comprehensive Questions

*Given an extended response to the following questions:*

**1. Describe an experiment to show that the steady current carrying wire produces a magnetic field around it. What is the direction of this magnetic field?**

Ans. See answer of question no 5 in the text.

**2. How the magnetic field of wire increases and resembles more like that from a permanent magnet, if the wire is formed in a circular coil? [Hint: Consider the magnetic field of a single coil and then a series of coils].**

Ans. See answer of question no 7 in the text.

**3. Explain the force on a current carrying wire in a magnetic field.**

Ans. See answer of question no 9 in the text.

**4. Explain the torque on current carrying coil in a magnetic field.**

Ans. See answer of question no 10 in the text.

**5. Explain the working of DC motor.**

Ans. See answer of question no 16 in the text.

**6. Describe the phenomena of electromagnetic induction. List the factors effecting electromagnetic induction.**

Ans. See answer of question no 11 in the text.

**7. Explain the direction of induced emf and how its relation to conservation of energy.**

Ans. See answer of question no 12 in the text.

**8. Sketch and describe the construction and working of AC generator.**

Ans. See answer of question no 17 in the text.

**9. Describe the phenomena of mutual induction.**

Ans. See answer of question no 15 in the text.

**10. What are transformers? On what principle it works? Also describe the purpose of transformers in AC circuit.**

Ans. See answer of question no 18 in the text.

## Numerical Questions

**Q1: A 1.5m long wire carries a current of 5A, at right angle to a uniform magnetic field of 0.04T. Determine the force exerted on the wire.**

Solution:

For right angle, $\theta = 90^\circ$

Given data:

Length of wire = $L$ = 1.5m

Current in wire = $I$ = 5A

Strength of magnetic field = $B$ = 0.04T

Required:

Force acting on wire = $F_m$ = ?

Calculation:

We know that,

$F_m = BIL\sin\theta$ ____________(1)

Putting the values in equation (1), we get,

$F_m = (0{\cdot}04 \times 5 \times 1{\cdot}5 \times \sin 90^\circ)N = 0{\cdot}3N$

$\boxed{F_m = 0{\cdot}3N}$ Ans.

**Q2: A wire carrying a direct current of 10·0A is suspended 5·0m east between a house and a garage perpendicular to the earth's magnetic field of $5{\cdot}0 \times 10^{-5}T$. What is the magnitude of the force that acts on the conductor?**

Solution:

Given data:

Current in the wire = $I$ = 10A

Length of wire = $L$ = 5m

Strength of magnetic field = $B = 5 \times 1^{-5}T$

For right angel or perpendicular, $\theta = 90^\circ$

Calculation:

We know that,

$F_m = BIL\sin\theta$ ____________(1)

Putting the values in equation (1), we get,

$F_m = (5 \times 10^{-5} \times 10 \times 5 \times \sin 90^\circ)N = 250 \times 10^{-5}N$

$\boxed{F_m = 2{\cdot}50 \times 10^{-3}N}$ Ans.

**Q3: A 10cm wire at 30° to uniform magnetic field of 0·06T is exerted by a force of 0·024N. What is the current flowing through the wire?**

Solution:

Given data:

Length of wire = $L$ = 10cm = 0·1m

Angle = $\theta = 30°$

Strength of magnetic field = $B = 0.06T$

Force acting on wire = $F_m = 0.024N$

Required:

Current through wire = $I$ = ?

Calculation:

We know that,

$$F_m = BIL\sin\theta$$

$$\Rightarrow \quad I = \frac{F_m}{BL\sin\theta} \quad \text{________}(1)$$

Putting the values in equation (1), we get,

$$I = \left(\frac{0.024}{0.06 \times 0.1 \times \sin 30°}\right)A = \left(\frac{0.024}{0.06 \times 0.1 \times 0.5}\right)A = 8A$$

$\boxed{I = 8A}$ Ans.

**Q4: If the current through the primary coil changes from -5A to +5A in 0.05s, such that the induced emf is 2.8V. What is the mutual inductance?**

Solution:

Given data:

Initial current = $I_i = -5A$

Final current = $I_f = 5A$

Time = $\Delta t = 0.05sec$

Induced emf = $\varepsilon_s = 2.8V$

Required:

Mutual inductance = $M$ = ?

Calculation:

We know that,

$$\varepsilon_s = -M\frac{\Delta I}{\Delta t} \Rightarrow \varepsilon_s = -M\left(\frac{I_f - I_i}{\Delta t}\right) \text{________(1)}$$

Putting the values in equation (1), we get,

$$\Rightarrow \quad \varepsilon_s = -M\left(\frac{5-(-5)}{0\cdot 05}\right) \Rightarrow 2\cdot 8V = -M \times \frac{10}{0\cdot 05}\frac{A}{sec}$$

$$\Rightarrow \quad M = -\left[\frac{2\cdot 8 \times 0\cdot 05}{10}\right] Henry = -0\cdot 014 \; Henry$$

$$\Rightarrow \quad M = -14\cdot 0 \times 10^{-3} H = -14\cdot 0mH$$

$$\boxed{M = -14\cdot 0mH} \quad Ans\cdot$$

Q5: A transformer connected to a 120V AC line is to supply 9600V for a neon sign. (a) What is the ratio of secondary to primary turns of the transformer? (b) If the transformer consisted of 275 primary windings, how many secondary windings would there be?

Solution:

Given data:

Voltage across primary coil = $V_p$ = 120V

Voltage across secondary coil = $V_s$ = 9600V

Required:

(i) Turns ratio = $\frac{N_s}{N_p} = ?$

(ii) If $N_p = 275$, then $N_s = ?$

Calculation:

(i) We know that,

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} \text{________(1)}$$

Putting the values in equation (1), we get,

$$\frac{N_s}{N_p} = \frac{9600}{120} = 80$$

$$\boxed{\frac{N_s}{N_p} = 80} \text{ Ans.}$$

(ii) For $N_p = 275$, we have,

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow N_s = \frac{V_s N_p}{V_p} \quad \text{________(2)}$$

Putting the values in equation (2), we get,

$$N_s = \frac{9600 \times 275}{120} = 22000$$

$$\boxed{N_s = 22000} \text{ Ans.}$$

**Q6: How many turns would you want in the secondary coil of a transformer having 400 turns in the primary, if it were to reduce the voltage from 220V AC to 3.0V AC?**

**Solution:**

**Given data:**

Number of turns in primary coil = $N_p = 400$

Voltage across primary coil = $V_p = 220V$

Voltage across secondary coil = $V_s = 3V$

**Required:**

Number of turns in secondary coil = $N_s = ?$

**Calculation:**

We know that,

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow N_s = \frac{V_s N_p}{V_p} \quad \text{________(1)}$$

Putting the values in equation (1), we get,

$$N_s = \frac{3 \times 400}{220} = 5.45$$

$$\boxed{N_s = 5.45} \text{ Ans.}$$

**Q7: A transformer steps down a main supply of 220V AC to operate a 12V AC lamp. Calculate the turns ratio of the windings.**

Solution:

Given data:

Voltage across primary coil = $V_p$ = 220V

Voltage across secondary coil = $V_s$ = 12V

Required:

$$\text{Turns ratio} = \frac{N_s}{N_p} = ?$$

Calculation:

We know that,

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} \quad \text{———} (1)$$

Putting the values in equation (1), we get,

$$\frac{N_s}{N_p} = \frac{12}{220} \Rightarrow \frac{N_s}{N_p} = 0.06$$

$$\boxed{\frac{N_s}{N_p} = 0.06} \text{ Ans.}$$

OOO

- حسد ایک آگ ہے جو انسان کو جلاتی ہے اور دوسروں کو عداوت پر اکساتی ہے۔
- رزقِ حلال کی تلاش عین عبادت ہے۔
- جھوٹ کبھی مت بولو کیونکہ ایک جھوٹ کو چھپانے کے لیے کئی جھوٹ بولنے پڑتے ہیں۔
- کسی کا دل نہ دکھاؤ۔ ہو سکتا ہے وہ آنسو تمہارے لیے سزا بن جائیں۔

CHAPTER

# 16 INTRODUCTORY ELECTRONICS

**Q1: Define electronics.**

Ans. "Electronics is the branch of applied physics that deals with the development of electron emitting devices and their utilization."

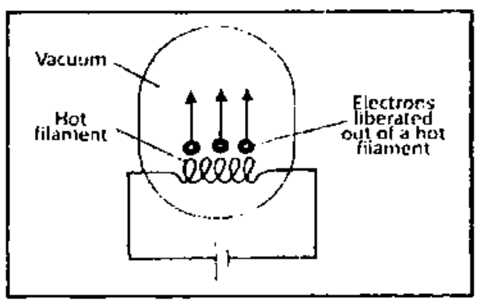
**Q2: Why electrons are emitted from an electrically heated metal filament? (OR) Define and explain thermionic emission.**

کسی گرم شدہ دھاتی فیلمنٹ سے الیکٹران کیوں خارج ہوتے ہیں؟(یا) الیکٹران کی تھرمل اخراج کی وضاحت کریں۔

Ans. Thermionic Emission [تھرمل اخراج]:

"The emission of electrons from certain metal due to heat is known as thermionic emission."

Explanation [وضاحت]:




There are some electrons which are revolving in the outermost orbits of an atom in a certain metal. These electrons can move freely and performs random motion. Such electrons are known as free electrons. These electrons can move freely through the metal.

However, an electron travelling outwards on the surface cannot escape as it is held back by the attractive forces of the atomic nuclei.

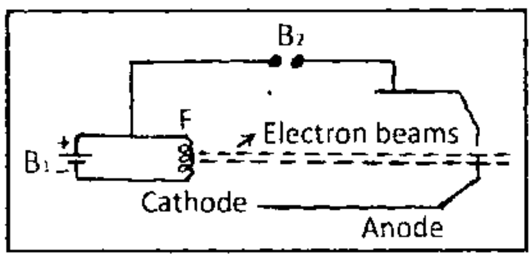
Now if we supply heat to the metal, then the electrons of outermost shells absorb the supplied heat energy and they becomes able to overcome the attractive forces of atomic nuclei. In this way, the electrons can escape from the surface of the metal. Such emission of electrons due to heat is known as thermionic emission.

**Q3: Describe the construction and working of electron gun.** الیکٹران گن کی ساخت اور کارگزاری بیان کریں۔

Ans. **Electron Gun:**

It is a device which is used to investigate the properties of electron beams.

**Construction:**




The electron gun consists of a glass tube as shown in the figure. The air from the tube is sufficiently evacuated so that to produce low pressure environment.

**Working:**

The filament "F" is heated by a battery "$B_1$" as shown in the figure. In this way, thermionic emission of electrons takes place. These electrons are then accelerated to a high speed by means of a battery "$B_2$". So these electrons shoots out from the hole of anode and thus a narrow beam of electrons is produce, which can be used for various purposes.

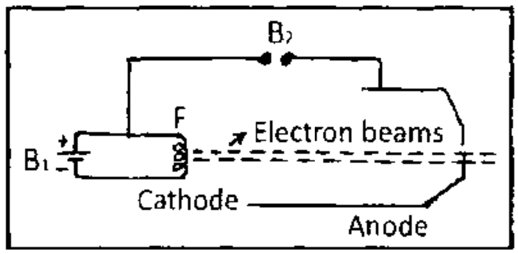
**Q4. What are cathode rays? How are cathode rays produced?** کیتھوڈ شعاعوں سے کیا مراد ہے؟ کیتھوڈ شعاعوں کو کس طرح حاصل کیے جاتے ہیں؟

Ans. Cathode Rays [کیتھوڈ شعاعیں]: (BISE Kohat, Bannu 2019)

The beams of electron are also known as cathode rays.

Production of Cathode Rays:

Consider an evacuated glass tube as shown in the figure. Let the filament "F" is heated by a battery "$B_1$" due to which electrons are emitted from filament. These electrons are then accelerated by means of battery "$B_2$" as shown in the figure. In this way, the electrons attain maximum momentum. These high energetic electrons are then allowed to pass through a narrow opening as shown in the figure. In this way, a beam of energetic electrons is produced which is also known as cathode rays.



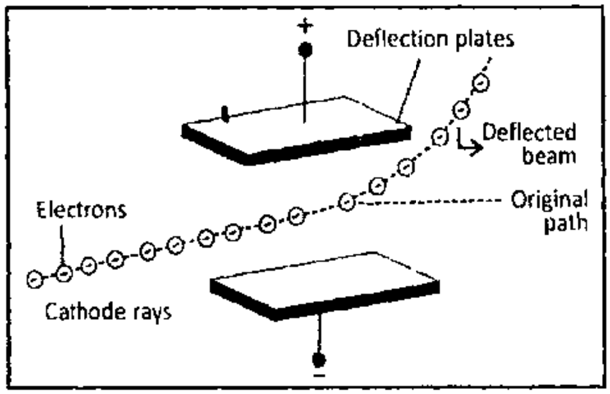

**Q5: What effect does an electric field and magnetic field have on the electron beam?**
الیکٹران بیم پر برقی فیلڈ اور مقناطیسی فیلڈ کا کیا اثر ہوتا ہے؟

Ans. (a) The Effects of Electric Field on Beams of Electrons: [الیکٹران کی بیم پر برقی فیلڈ کے اثرات]

The electric field can affect the path of free electrons. We can set up an electric field by applying a potential difference across the two parallel plates, as shown in the figure.

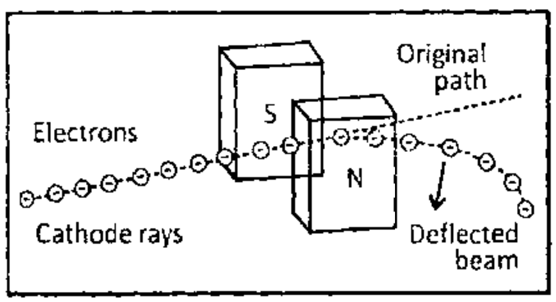
When a beam of electrons passes between the two

plates, it is deflected by the electric field from its original path and follows a parabolic path. As the electrons are negatively charged particles, so its beam deflects towards the positive plate as shown in the figure.




The degree of deflection depends upon the strength of electric field. If the electric field is stronger, then greater will be the degree of deflection and if the electric field is weaker, then smaller will be the degree of reflection.

**b) The Effects of Magnetic Field on the Beam of Electrons: [الیکٹران کی بیم پر مقناطیسی فیلڈ کا اثر]**




The magnetic field can effect the path of free electrons. We can set a magnet field by placing two poles of the magnet at right angle to the beam of electrons as shown in the figure.

The magnetic force deflects the beam of electrons from its original path and thus follows a circular path as shown in the figure. This shows that the magnetic field can effect the path of charged particles.

**Q6: What is the difference between analogue and digital electrons?** اینالوگ اور ڈیجیٹل الیکٹرانکس میں کیا فرق ہے؟

Ans. a) Analogue Electronics:

The branch of electronics which consists of such circuits which processes analogue quantities are known as analogue electronics.

Analogue Quantities: Those quantities whose values vary continuously or remain constant are known as analogue quantities.

For example, the temperature of air changes continuously during day and night. So temperature is an analogue quantity.

If we draw a graph for various values of temperature and time, we get a curve as shown in the figure.

b) Digital Electronics:

The branch of electronics which consist of such circuit which processes digital data are known as digital electronics.

Digital Data: Digital electronics uses only two digits i.e., zero [0] and one [1]. The data can be processed easily because the whole data is provided in binary system. The digital electronics is used in computers, telephone system, radar system, industrial machines, medical equipments etc.

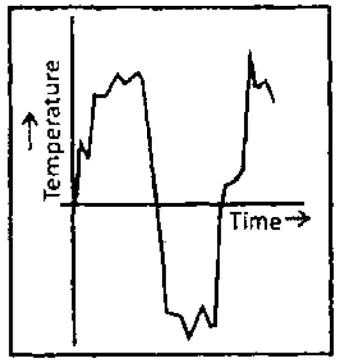
**Q7: Explain the construction, working principle and uses of C.R.O.**

سی۔ آر۔ او (C.R.O) کی ساخت، کارگزاری اور استعمال بیان کریں۔

Ans. Cathode Ray Tube (OR) Cathode Ray Oscilloscope

**[C·R·O]:**

*The C·R·O is a graph plotting device with the help of which we can see the waveform of a repetitive electronics signals·*

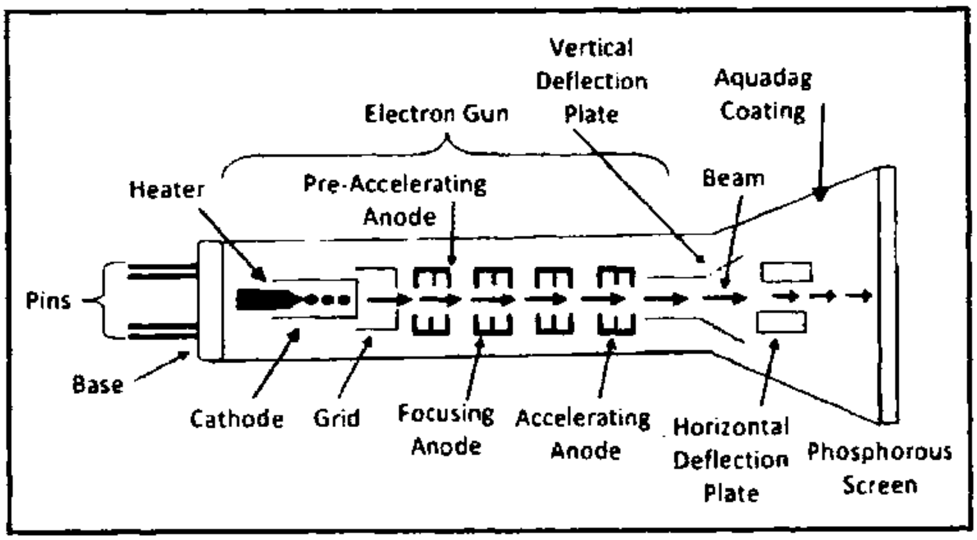



**Construction & Working [ساخت اور کارگزاری]:**

*(BISE Swat, Mardan, Kohat, Bannu 2019)*

*The C·R·O consists of the following parts:*

1. *Electron Gun*
2. *Deflecting plates*
3. *A fluorescent screen*




*1) **Electron Gun:** It consists of a grid, which is connected to a negative potential· If we apply high potential, the electrons will be pushed easily from the grid towards the anode and then towards the screen· The number of electrons reaching the screen determines the brightness of the light· Thus the negative of the grid can be used as a brightness control·*

The anode is at positive potential· Due to high voltage, the electron passes rapidly through the anode hole and thus a narrow beam of electrons is produced·

2) The Deflection System: The deflection system of C·R·O consists of two pairs of plates i·e· x-plates and y-plates· These plates can deflect the beam of electrons when voltage is applied to them· When voltage is applied to x-plates, they deflect the electrons beam in horizontal direction· When voltage is applied to y-plates, they deflect the electrons beam in vertical direction·

3) The Fluorescent Screen: The screen of C·R·O is coated with a fluorescent salt i·e·, zinc sulphide or phosphorus· When the beam of electrons hits the screen, the salt produce a flash of light and thus we can see a bright spot on the screen·

Uses of C·R·O:

1· The C·R·O is used in T·V·
2· The C·R·O is used in computers·
3· The C·R·O is used in laboratory to study the waveforms of a signal·
4· The C·R·O can be used to estimate small time intervals·
5· The C·R·O can be used for displaying the wave form of a given voltage·

6. The C.R.O can be used as A.C circuits or D.C circuits.

**Q8: Discuss the basic operations of digital electronics.**

Ans. In daily life, there are several examples which involve only two levels. For example, ON and OFF represents the two levels or states of a given electric circuit. Similarly, true or false represents the two levels of a given statement. Such things which can have only two possible states are known as Boolean variables. The two states of Boolean variables are usually represented by two digits i.e. 0 and 1.

The Boolean variables can be used to determine the state of a given system. For example, a closed switch is represented by "1" and an open switch is represented by "0".

The Boolean variables can be used in the form of input and output data. The output of any two input and output data. The output of any two input data can be obtained in different manners by using logic gates.

**Q9: Define logic gates. Describe the operation of AND, OR, NOT, NAND and NOR logic gates by drawing their symbols and truth tables.**

Ans. <u>Logic Gates:</u>

The logic gates are electronic circuits which operate

on one or more input signals to produce standard output signals.

**Explanation:**

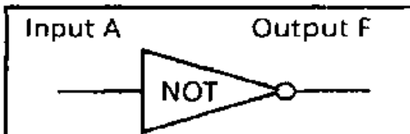
The logic gates play an important role in various circuits of a computer system. We can explain the working of logic gates with the help of logic tables, which is known as truth table.

The truth table gives us the logical uses of two binary numbers i.e., "0" and "1". The logic "0" stands for OFF and logic "1" stands for ON.

The logic gates uses one or more than one input signals and gives a single output signal.

**Types of Gates [Example of Gates]:**

1) **NOT Gate:** The NOT gate is also known as inverter, because it changes ON to OFF and OFF to ON. i.e., if the input is "0", then output will be "1", and if the input is "1", then the output will be "0", as shown in truth table.




Symbol of NOT gate

| NOT Gate | |
|---|---|
| Input A | Output F |
| 0 | 1 |
| 1 | 0 |

2) AND Gate: In case of AND gate, the output will be ON only, if both inputs "A" and "B" are ON. In other words we can say that, output will be "1", if both input are "1", while the output will be "0" if both input are "0", or any one input is "0".

3) OR Gate: In case of OR gate, the output will be ON if both input or any one input is ON. In other words we can say that, the output will be "0" if both input are "0". While the output will be "1", if both input or any one input is "1".

4) NAND Gate: In case of NAND gate, the output will be ON if both input are OFF or only one of them is OFF. In other words we can say that, output will be "1" if both input or any one of them is "0". While the output will be "0" if both input are "1".

5) NOR Gate: In case of NOR gate, the output will be ON if both input are OFF. In other words we can

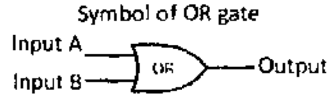
Symbol of AND gate




AND Gate

| Input | Input | Ouput |
|---|---|---|
| A | B | F |
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

Symbol of OR gate




OR Gate

| Input | Input | Output |
|---|---|---|
| A | B | F |
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

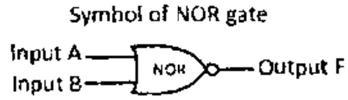
Symbol of NAND gate




NAND Gate

| Input | Input | Output |
|---|---|---|
| A | B | F |
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

Symbol of NOR gate




NOR Gate

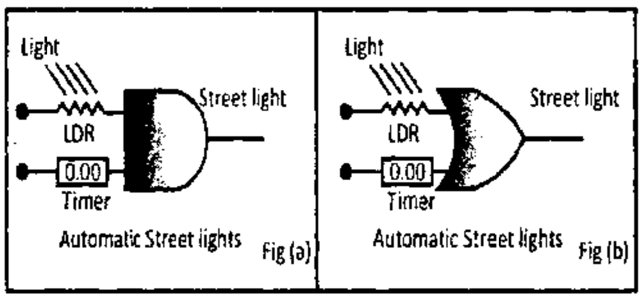
| Input | Input | Output |
|---|---|---|
| A | B | F |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

say that, the output will be "1" if both input are "0". While the output will be "0" if both input or any one of them is "1".

**Q10: Explain simple uses of logic gates in (a) automatic light bulb switching (b) textile coloring plant.**

Ans. Uses of Logic Gates:

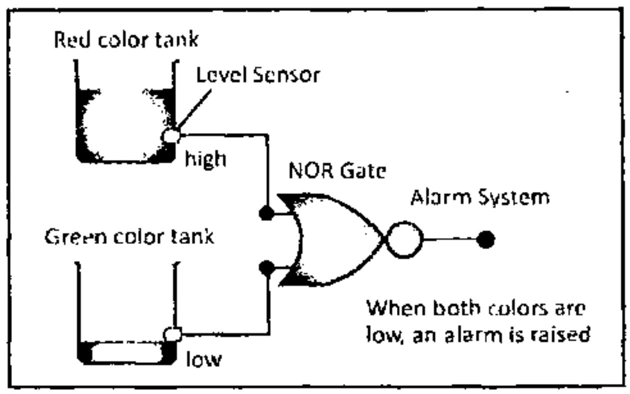
a) Automatic Light Bulb Switching: If you desire to automatically switch the street lights ON and OFF, after appropriate time and light level, you can use an AND gate.




During day when light shines on light dependent resistor (LDR), the resistance is high and current in the wire is low [0]. In the evening when light fades out, the resistance of LDR decreases and it starts conducting and turns to high [1]. But the light will not glow until the timer time is not reached after which it would also turn high [1]. When both the terminals are high the street will turn up. The schematic representation is shown in the figure (a). On the other hand, if we want to turn the light ON when either light is low or timer time is reached, we can use an OR gate, as shown in figure (b).

b) Textile Coloring Plant: A textile coloring plant uses two tanks to store red color and green color. Each tank has a sensor that detects when the color

level drops to 25% of full, the sensors produce a high level of 5V when the tanks are more than one-quarter full. When the volume of color is a tank drops to one-quarter full or less, the sensor puts out a low level of 0V. Manufacturer requires that an alarm is raised when both tanks are more than one-quarter empty. A NOR gate with its two inputs connected to the tank level sensors and its output connected to the indicator alarm system is shown in figure. Such that if red color tank and green color tank are above one-quarter full, the signal is low [0V], even if one tank reduces to less than 25% of full.




As soon as both sensor outputs are low [0V], indicating that both tanks are less than one-quarter full, the NOR gate output is high [5V] and alarm is raised. Here NAND gate circuitry can be used to indicate by a green light that both tanks are full.

## Exercise

Q1: Choose the correct answer.

1. Cathode rays are beam of:
   a. Protons   b. Electrons✓
   c. Ions   d. Neutrons
2. If electric field is applied parallel to the direction of electron beam, the electrons will:
   a. Speed up   b. Slow down✓
   c. Deflect   d. Not change its state
3. If magnetic field is applied parallel to the direction of electron beam, the electrons will:
   a. Speed up   b. Slow down
   c. Deflect   d. Not change its state✓
4. The electronic circuit that gives high [1] output when all its input are high [1] is called......gate.
   a. AND✓   b. OR
   c. NAND   d. NOR
5. The electronic circuit that gives high [1] output when one or more of its input are high [1] is called....gate.
   a. AND   b. OR✓
   c. NAND   d. NOR
6. The electronic circuit that gives low [0] output when all its input are high [1] is called.......gate.
   a. AND   b. OR
   c. NAND✓   d. NOR
7. The electronic circuit that gives low [0]

output when one or more of its input are high [1] is called...gate.

a. AND b. OR
c. NAND d. NOR✓

8. The Boolean equation for OR gate is:

a. $X=AB$ b. $X=A+B$✓
c. $X=\overline{AB}$ d. $X=\overline{A+B}$

9. The Boolean equation for NAND gate is:

a. $X=AB$ b. $X=A+B$
c. $X=\overline{AB}$✓ d. $X=\overline{A+B}$

## Conceptual Questions

Give a brief response to the following questions:

**Q1: What are free electrons?
(BISE Swat, Malakand 2019)**

Ans. Those electrons with the help of which a material can conduct electricity are known as free electrons.

Reasons and Explanation:

In metallic conductor the outermost shell electrons are called valence electrons. These valence electrons are not bound to particular atoms and hence move freely in conductor. These electrons which move freely in conductor like the gas molecules are called free electrons. The material containing free electrons can conducts heat and electricity.

**Q2: What is the function of accelerating anode in electron gun?**

Ans. The function of accelerated anode is to

increase the energy of electron beam.

**Reasons and Explanation:**

An electron gun is an electrical device which produces a narrow, collimated electron beam with a specific K.E. This is generally used in computers, TVs and CROs.

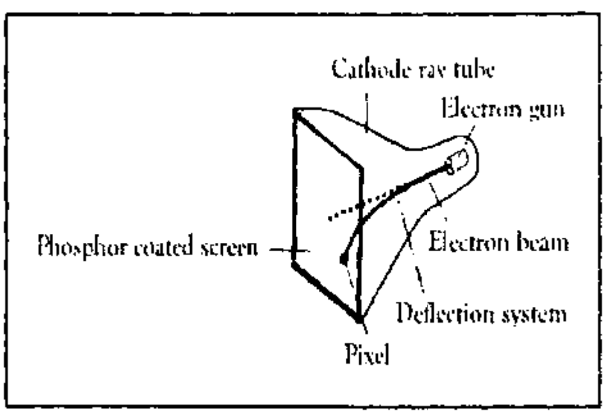
In electron gun, the filament heats up a cathode, which emit thermal electrons and forms an electron cloud near the cathode surface. The accelerating anode attracts these electrons and accelerates them [in the form of beam] towards the screen. The electrons hitting the screen produce fluorescence for creating images on it.

**Q3: If the electron beam in a television tube is striking just one point on the screen at a time, how can we get a full picture? Explain.**

Ans. We get a full picture on the screen of television, because the visible light from the central spot spread over the whole screen by means of deflecting horizontal and vertical plates system.

**Reasons and Explanation:**

There is an electron gun in television tube which produces a narrow beam of energetic electrons. The electrons are directed towards the screen of television. The inner surface of



the screen is coated with fluorescent material like phosphor. When the beam of electrons hits the inner surface of the screen, it produces a spot of visible light on the screen. This spot is called pixel. There is a system of deflecting horizontal and vertical plates which scan the beam of electron on the whole screen. As a result we see the images of the concern objects on the screen.

**Q4: Why image is distorted when a magnet is brought close to old television screens or monitors with cathode ray tube inside?**

Ans. When a magnet is brought closer to the screen of television, the image is distorted.

Reasons and Explanation:

We know that beam of electron is used in cathode ray tube which hits the screen of television and produce the images of the objects.

When a magnet is brought near the screen of an old television, the magnetic force of the magnet acts on the beam of electron. As a result of this magnetic force, the electron deflects slightly from their original path. As a result the beam of electron will hit the screen in irregular pattern and thus the image will be distorted.

**Q5: Assuming that cathode rays are a beam of charged particles, how could you demonstrate that there particles are negatively charged? Explain.**

Ans. The cathode rays particles are negatively charged.

*Reasons and Explanation:*

*The following demonstrations support the evidence that cathode rays are negatively charged electrons:*

1. *When cathode rays are created then they move towards the anode of the discharge tube due to electrostatic force of attraction which shows that they are negatively charged particles.*
2. *When an electric field is applied in the discharge tube the cathode rays experiences an attractive force towards the positive plate of the applied electric field which also shows that they have negative charge.*
3. *By applying the magnetic field these rays starts moving in a circle. By applying right hand rule, we can prove that they have negative charge.*

*Q6: If there are 4 inputs in any logic gate, how many combinations are possible?*

*Ans. There will be 16 possible combinations for 4 inputs.*

*Reasons and Explanation:*

*The number of possible combination for given inputs is given by,*

*Number of possible combination =* $N = 2^n$ ______ *(1)*

*In equation (1), "n" represents the number of inputs and "N" represents the number of possible combination.*

*Now for "4" inputs, we put n = 4 in equation (1), so we get,*

$$N = 2^4 = 2 \times 2 \times 2 \times 2 \Rightarrow \boxed{N = 16}$$

*Thus there are 16 possible combinations for 4 inputs.*

**Q7: What conditions produce a high (1) output for an AND gate and NOR gate?**

Ans. 1. Conditions for AND Gate:

The Boolean equation for AND gate is given by,

$$X = A \cdot B \quad ________ (1)$$

Equation (1) shows that the output of AND will be high i.e. "1" if both inputs are high i.e. "1". The truth table for AND gate is given below:

| Input "A" | Input "B" | Output "X" |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

2. Condition for NOR Gate:

The Boolean equation for NOR gate is given by,

$$X = \overline{A + B} \quad ________ (2)$$

Equation (2) shows that the output of NOR gate will be high i.e. "1" if both inputs are low i.e. "0". The truth table for NOR gate is given below:

| Input "A" | Input "B" | Output "X" |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

**Q8: What are the algebraic Boolean expressions to represent the output of AND, OR, NOT, NAND and NOR gates?**

Ans. The algebraic Boolean expressions give us the

details about the output of different logic gates. The algebraic Boolean expressions for various logic gates are given below:

1. AND Gate: For AND gate, the algebraic Boolean expression is given by, $\boxed{X = A \cdot B}$

2. OR Gate: For OR gate, the algebraic Boolean expression is given by, $\boxed{X = A + B}$

3. NOT Gate: For NOT gate, the algebraic Boolean expression is given by, $\boxed{X = \bar{A}}$

4. NAND Gate: For NAND gate the algebraic Boolean expression is given by, $\boxed{X = \overline{A \cdot B}}$

5. NOR Gate: The algebraic Boolean expression for NOR gate is given by, $\boxed{X = \overline{A + B}}$

## Comprehensive Questions

Given an extended response to the following questions:

**1. Why electrons are emitted from an electrically heated metal filament?**

Ans. See answer of question no 2 in the text.

**2. What are cathode rays? How are cathode rays produced?**

Ans. See answer of question no 4 in the text.

**3. Describe the construction and working of electron gun?**

Ans. See answer of question no 3 in the text.

*4. What effect does an electric field and magnetic field have on the electron beam?*

*Ans. See answer of question no 5 in the text.*

*5. Describe the working principle of cathode ray oscilloscope [CRO] and make list of its uses.*

*Ans. See answer of question no 7 in the text.*

*6. What is the difference between analogue and digital electronics?*

*Ans. See answer of question no 6 in the text.*

*7. Define logic gates. Describe the operation of AND, OR, NOT, NAND and NOR logic gates by drawing their symbols and truth tables.*

*Ans. See answer of question no 9 in the text.*

*8. Explain simple uses of logic gates in (a) Automatic light bulb switching (b) Textile coloring plant.*

*Ans. See answer of question no 10 in the text.*

OOO

- مشکلات کو دُور کرنے، خواہشات کو دبانے اور تکالیف کو برداشت کرنے سے انسان کا کردار اعلیٰ، مضبوط اور پاکیزہ ہو جاتا ہے۔
- جب تک کسی شخص کا پوری طرح حال معلوم نہ ہو اس کی نسبت بزرگی کا اعتقاد نہ رکھو۔
- ظالم حاکم کے روبرو انصاف کی بات کرنا بڑی جہاد ہے۔
- جس پر نصیحت اثر نہ کرے اس کا دِل نورِ ایمان سے خالی ہوتا ہے۔

CHAPTER 17

# INFORMATION & COMMUNICATION TECHNOLOGY

**Q1: Define and explain information technology [IT].**
انفارمیشن ٹیکنالوجی کی تعریف اور وضاحت کریں۔ نیز اس کی اہمیت بیان کریں۔

**Ans. Information Technology:**

"The scientific method of storing, protecting, processing, transmitting, receiving and retrieving information is known as **information technology**."

**Explanation [وضاحت]:**

In the present age, new techniques, skills and knowledge are discovering rapidly due to modern sciences. The computers, internet, fax machine, telephone, cell phone, radio, CDs, T.V, etc have devices are the powerful sources of communication. These devices help us to transmit information in the form of sound, written shape or pictures. For communication and transmission, the information is first converted into electrical signals, radio waves or light signals. These signals or waves propagate with very high speed. The electrical signals are transmitted through conducting wires. The radio waves propagate through air and space. The light signals are sent

through optical fibers.

**Importance of I.T [انفارمیشن ٹیکنالوجی کی اہمیت]:**

1. The whole world has become a global village due to information technology.
2. We can store data and information in hard disk, CDs, USB etc due to information technology.
3. We can protect data and information from viruses and other harmful effects due to information technology.
4. We can process data and information with the help of computers and other machines due to information technology.
5. We can receive and retrieve data and information due to information technology.
6. The information technology can be used to maintain the state of traffic.
7. Information technology has made teacher and students communication easier and fastest.

**Q2: What is information and communication technology [IT]? Explain briefly its components**
انفارمیشن اور کمیونیکیشن ٹیکنالوجی سے کیا مراد ہے؟ اس کے اجزاء مختصر طور پر بیان کریں۔

Ans. (1) **Information:**

When data is processed and becomes useful, then it is called information.

(2) **Communication Technology:**

The infrastructure and components that enable

modern computing system to create, analyze and communicate information is called communication technology.

**Components of information and communication technology [ICT]:**

The ICT system consists of the following components:

**a) Data and Information:** Data is simply facts or figures – bits of information, but not information itself. When data is processed, interpreted, organized, structured or presented so as to make them meaningful or useful, they are called information. It may be in the form of text, sound, graphic or figure that has been processed in such a way as to be meaningful to the person who receives it.

**b) Hardware:** In information technology, hardware is the physical aspect of computers, telecommunications, and other devices. Hardware is the physical parts of machinery that we can touch. For example, mouse, keyboard, printer etc.

**c) Software:** A computer needs to be told what to do, software is the applications and programming instructions that tell your computer that what to do. Software enables you to use a computer for things such as playing games, writing an essay or listening to music. These are machine – readable instructions that

direct the circuitry within the hardware parts to store, process, transmit, receive and retrieve information in a specific manner.

**d) Procedures:** These are set of instructions and rules to design and use information system. These are written in manuals and documents for use. These rules or methods may change from time to time. The information system must be flexible to incorporate these changes.

**e) Human Resource:** It is people who design and operate the software, they feed input data, build the hardware.

**Q3: Explain the flow of information. Describe how information is transmitted as electrical signal through wires, light signals through optical fibers and radio waves through air / vacuum?**

**Ans. Flow of Information:**

Flow of information is a particular view that focuses on the path and means followed by information entities.

**1) Transmission of Electrical Signal through Wire:** Data or information can be transmitted and received over a wire-based communication technology. The information is converted to electrical signals at the transmitter, which is sent through wires [twisted pair, coaxial cable etc] and information is converted back to original

form at receiver's end. Examples include telephone networks, cable television and internet access.

For example, in figure (a), a simple telephone model sound [voice] is converted into electrical signals through mouth piece and sent through electrical wires [twisted pair] and converted back to sound [voice] through ear piece at the receiver.

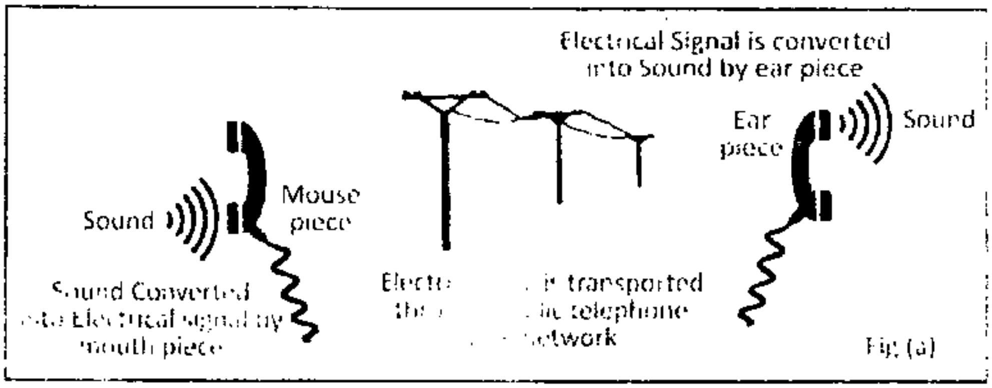


Fig (a)

Electrical wire may be used to transmit both analog and digital transmission. For analog signals, amplifiers are required about every few kilometers and for digital transmission [using either analog or digital signals], repeaters are required every kilometer, depending upon the type of wire used.

**2) Transmission of Electrical Signal through Optical Fibers:** An optical fiber transmits a signal-encoded beam of light by means of total internal reflection. Total internal reflection can occur in any transparent medium that has a

higher index of refraction than the surrounding medium.

The information is converted into electrical voltage signals this varying voltage is used to produce light. Two different types of light source are used in fiber optic systems: the light emitting diode [LED] and the injection laser diode [ILD]. Both are semiconductor devices that emit a beam of light when a voltage is applied. The LED is less costly, operates over a greater temperature range and has a longer operational life. The ILD, which operates on the laser principle, is more efficient and can sustain greater data rates. Figure shows the principle of optical fiber transmission.

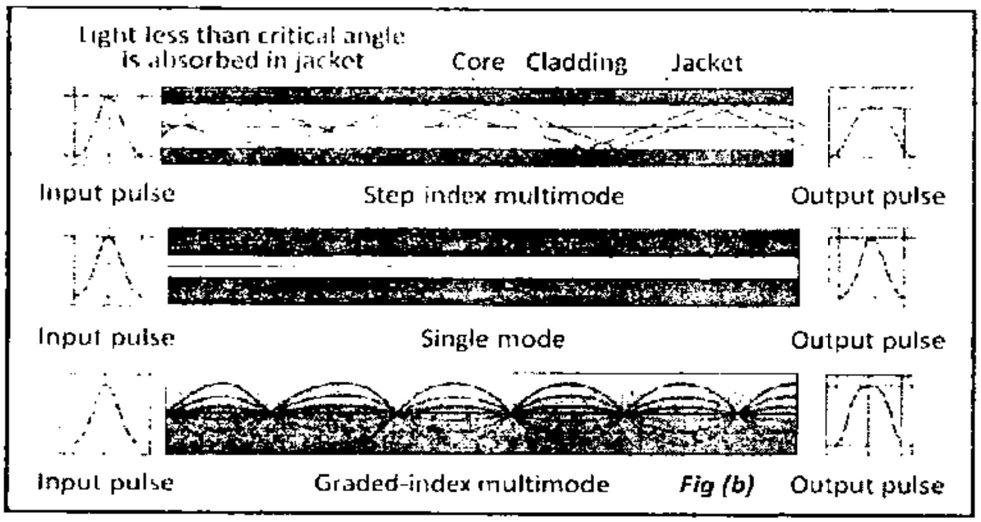


*Fig (b)*

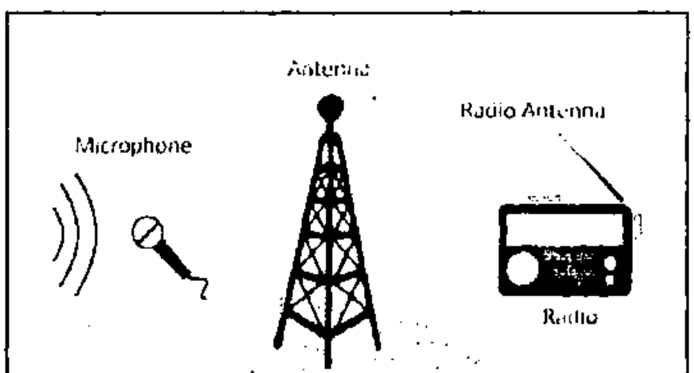
a) __Step-Index Multimode:__ Light from a source enters the cylindrical glass or plastic core. Rays at low angles are reflected due to total inter-

nal reflection and travel along the fiber; other rays are absorbed by the surrounding material. This form of propagation is called step-index multimode. This type of fiber is best suited for transmission over very short distances.

b) **Single-Mode:** When the fiber core radius is reduced to the order of a wavelength, only a single angle or mode can pass. Single-mode is typically used for long distance applications, including telephone and cable television.

c) **Graded-Index Multimode:** When the index of refraction at the center of the core is made is higher and reduced gradually, light in the core curves helically due to variation in the index of refraction. the shortened path and higher speed allows light at the periphery to arrive at a receiver at about the same time as the straight rays in the core axis. Graded-index fibers are often used in local area networks [LAN].

d) **Transmission of Radio-Waves through air or Space:** Electrical signals representing information from a microphone, a TV camera, or a computer [transmitters] can be



sent from one place to another place using radio waves.

For transmission of a signal, radio-frequency electrical energy from the transmitter is converted into electromagnetic energy by the antenna and radiated into the surrounding environment [atmosphere, space, water]. For reception of a signal, electromagnetic energy falling on the antenna is converted into radio-frequency electrical energy and fed into receiver.

**Q4: Define telecommunication.**

Ans. "The method that is used to communicate informations to far off places instantly is known as telecommunication."

**Q5: Write a note on telephone.**

Ans. Telephone [ٹیلی فون]

(BISE Peshawar, Kohat, Bannu 2019)

A telephone is a telecommunication device which can transmit and receives sound waves. It is a point to point communication system whose basic function is to allow two people to talk to each other separated by a large distance from one another.


Telephone

When we talk over a telephone, its microphone

converts the sound signals into electrical signals. The electrical signals travel through the telephone cables. At the other end the telephone receiver is fixed which receives the electrical signals. The receiver converts the electrical signals back into sound signals. In this way, we hear the sound over a long distance.

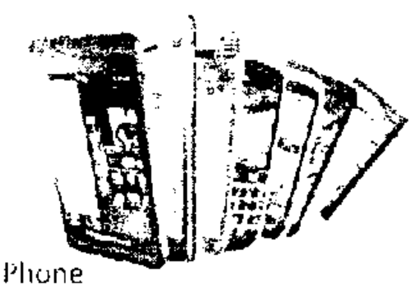
**Q6: What is a cell phone? Explain its working.**

Ans. Cell phone:

A cell phone is really a versatile [[illegible]] radio, because it can send and receive radio signals. We can talk through cell phone to any person in any part of the world.

Structure and Working:

A cell phone consists of a compact speaker, a microphone, a keyboard, a display screen, a powerful circuit board with microprocessors, as shown in the figure.



Cell Phone

The cell phone works on the basis of digital technology. It converts data into small packets of 0's and 1's.

Uses of Cell Phone:

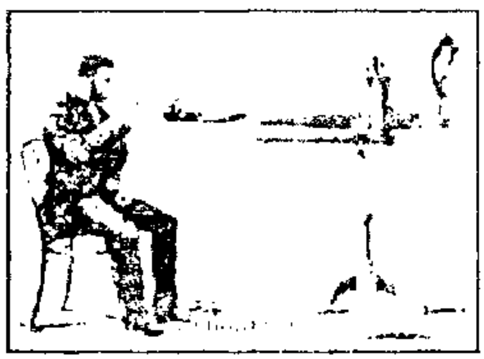
1. We can talk through cell phones world-wide.
2. We can send sms and mms through cell

phone.

3. We can send email and pictures through cell phone.
4. We can made video of various functions through cell phone.
5. We can enjoy music, games, movies through cell phone.
6. We can use cell phones as a torch.
7. We can hear radio programs through cell phones.
8. We can do mathematical operations i.e. additions, subtraction, multiplication and division through cell phone.
9. We can use cell phones as a watch and calendars.

**Q7: Write a note on photo phone.**

Ans. Photo Phone: (BISE Peshawar, Kohat, Bannu 2019)



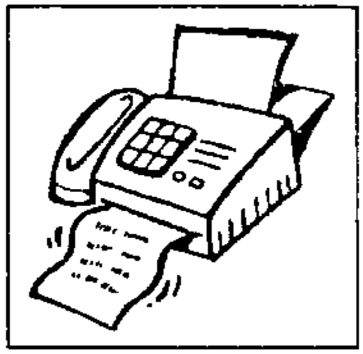
It is a device which can transmit sound waves on a beam of light. The photo phone was discovered by Alexander Graham Bell in 1880. The photo phone worked by projecting voice through an instrument towards a mirror. The vibrations in the voice caused similar vibrations in the mirror. Bell directed sunlight into the

mirror, which captures and projected the mirror's vibrations. These vibrations were transformed back into sound signals at the receiving end of the projection.

The modern optical fibers works on the principle of photo phone.

**Q8: What is a fax machine? Explain its structure and working.**

Ans. Fax Machine:



It is a device which is used to send documents to other locations without changing the physical versions of the document. The information is instantly converted to an electronic signal and sent through a phone line to the other location.

a) Sending Faxes:

For sending the documents through a fax machine, the paper is put in a scanner device and dials the relevant fax number. The scanning machines read the paper and divide it into lines of information that shows where the paper is dark, white or colour. Once the document has been scanned, the fax machine sends the information through the phone lines to the fax ma-

chine specified by the fax number.

**b) Receiving Faxes:**

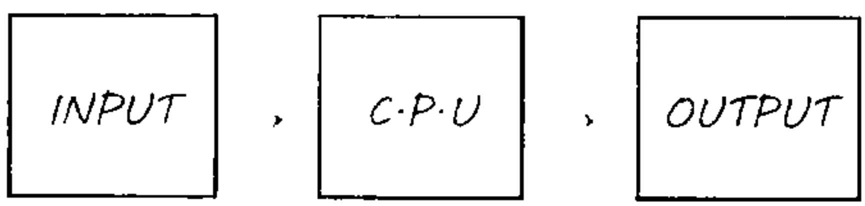
The specified fax machine receives the incoming signals. It converts the incoming signals back into its black, white and colour parts. The information is then replicated by the fax machine's printer section. In this way, the documents are sent to other locations without changing its physical version.

**Q9: What is a computer? Discuss the various parts of the computer.**

**Ans. Computer:**

It is an electronic machine which accepts input, process it internally and finally prepares information for output.

**Main Parts of Computer:**




The main parts of computer are given below:

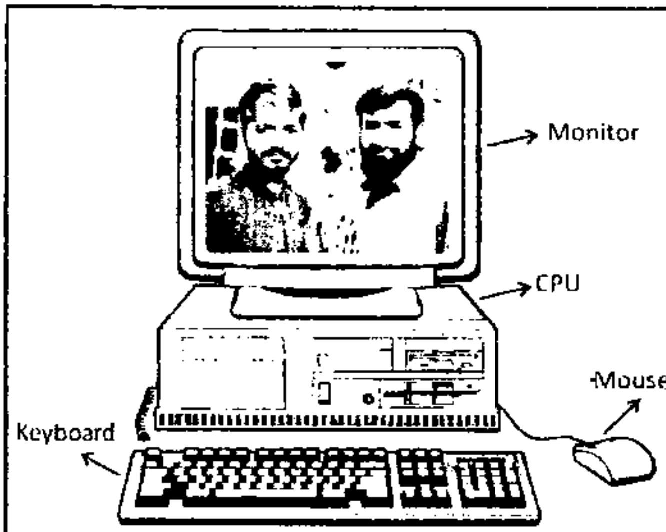
**1) Input Unit:**

It is called the receiving section of the computer with the help of this section, data and instructions are sent inside the computer sys-

tem· The common input devices are mouse, keyboard, CDs, USB and floppy disc etc·

2) Central Processing Unit [CPU]:

It is also known as the brain of the computer· It receives the data and instruction from input devices and then makes them analyzed andv organized· It consists of control unit



Main parts of a computer

and memory units· All types of arithmetic and logical operation are performed in CPU·

3) Output Unit:

When the CPU analyze and organized the input data, then well organized information are prepared· These information are sent to the output unit· Screen [monitor] and printer are the common output devices· Through screen, we can view the organized information, while through printer, we can get a copy of the organized information· We can also transfer the output information through CDs, USB and floppy disc etc·

## Importance of Computer:

1. The computer technology has played an important role in the development of modern world.
2. The computer has made our work easy and fast.
3. The computer prepares output information with accuracy.
4. The computer provides us the facility of internet through which we can communicate with any part of the world.
5. We can compose any type of documents through computers.
6. We can do logical and arithmetic operations through computers.
7. We can use computers for data managing and graphic designing.
8. We can use the facility of internet through computers.
9. We can store office data and records of various departments in computers.
10. We can enjoy music, dramas, movies through computer.
11. The jewelers can use computer for measuring purposes.
12. Nadra department use computer network for designing, preparing and verifying of NIC.

**Q10: What is an electronic mail? Discuss its importance.**

*Ans. Electronic Mail [E-mail]:*

*The electronic mail is a method with the help of which digital messages can be exchanged among users. Such service can accept, forward, deliver and store messages. The sender can send the message any time and the recipient can read the message anytime.*

*The email messages consists of three components i.e. envelope, the message header and the message body. In envelope, the message is enclosed. The message header gives the brief summary of the message. The message body consists of all information send by the sender.*

***Importance of Email:***

1. *Through email, we can communicate with any person in any part of the world.*
2. *We can send our academic record to any department for getting service or admission through email.*
3. *A teacher can send information to his / her student through email.*
4. *We can store data / information in email.*
5. *We can send Eid cards, wedding cards through email.*
6. *We can send picture and graphics through email.*

**Q11: What is internet? Discuss the importance of internet.**

Ans. **Internet:**

The internet is an international network of computers through we can communicate with any person in any part of the world.

**Explanation:**

Internet is a global web of more than one million nets in which more than 50 million computers are operating and almost 200 million people participate throughout the word. The number is increasing day by day.

**Importance of Internet:**

1. We can share information during day and night through internet.
2. We can download application form or result card through internet.
3. We can use ATM card for receiving or transferring money through internet.
4. We can do shopping through internet.
5. We can pay utility bills through internet.
6. Teachers / students communication is possible through internet.
7. We can send information / documents to any person in any country through internet.
8. We can search for jobs and admission through internet.
9. We can do business through internet.

10. Internet provides us very low cost and fastest way of communication.
11. Internet provides us safe and guaranteed services.
12. We can call to any person at very low rate through internet.
13. We can use internet for chatting purposes.
14. We can use internet for entertainment.
15. We can get help from libraries world wide through internet.
16. We can download picture / graphics etc. through internet.
17. We can watch international games through internet.

**Q12: Write a note on audio and video cassettes.**

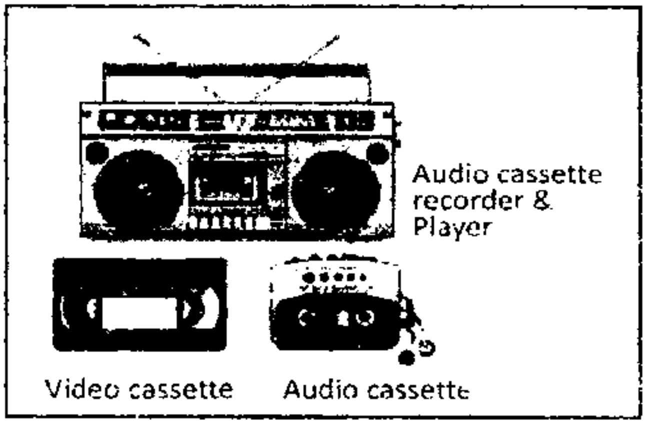
**Ans. Audio and Video Cassettes:**

The audio video cassettes consist of a tape which is made from magnetic material. Sound is saved in the form of particular magnetic field on this tape. For this purpose, the microphone changes the sound waves into electric pulses.

The magnetic tape of the cassette is moved through the head of audio cassette recorder which is infact an electromagnet. A wire is wrapped on the electromagnet. When the current in the wire is allowed to change, the magnetic field linked with the wire also changes and

as a result, the magnetic tape is magnetized in a particular form. In this way, sound is stored in a specific magnetic pattern in this tape.

Now for hearing the sound again, the tape is allowed to move into the play back head. The magnetic field changes on the tape and as a result current signals are in-



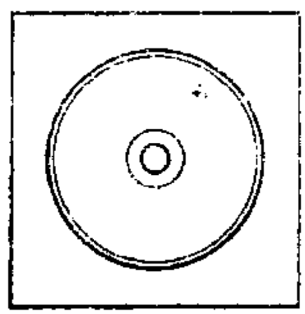

duced in the coil. These signals are amplified and then sent to the loud speakers which reproduce the recorded sound. In case of video tape, pictures are also recorded along with sound.

**Q13: What is compact disc? Explain.**

Ans. Compact Disc [CD]:

It is a storage device, on which the pulses are recorded in the form of tiny notches.

The information stored on CDs can be read or taken with the help of laser beams. A CD turns with high speed around x-axis. During this time, the laser beam shines on the disc. The light



from CD is reflected at various angles.

The reflected light is picked up by a detector and is converted into electric pulses. These pulses are sent into the loud speaker where it is converted into sound. In case of video CD, pictures are also recorded along with sound.

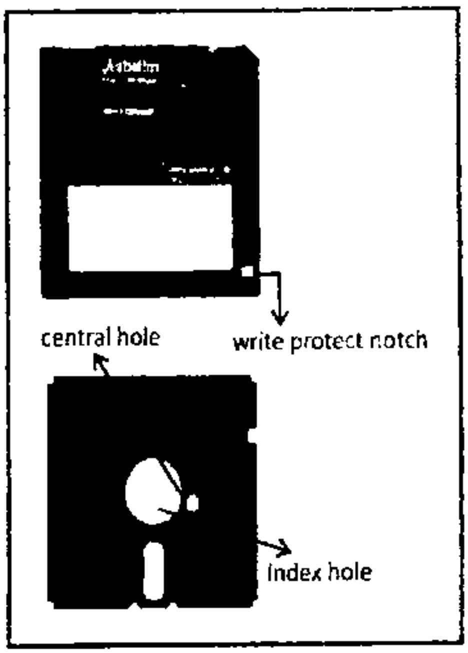
**Q14: Write a note on floppy disk.**

Ans. Floppy Disc:

It is a storage device which is made from flexible plastic material. It is coated with ferromagnetic compound and is enclosed in a protective jacket having several holes as shown in the figure. The details of these holes are given below:

**1) Write Protect Notch:**

The write protect notch is used for two purposes. If it is open, then no data can be entered on the disc. Also no changes can be done in the previous data. If it is closed, then data can be entered on the disc. Changes can be also done in the previous data.




**2) Central Hole:**

Due to central hole, the disc can rotate about a fixed axis.

**3) Index Hole:**

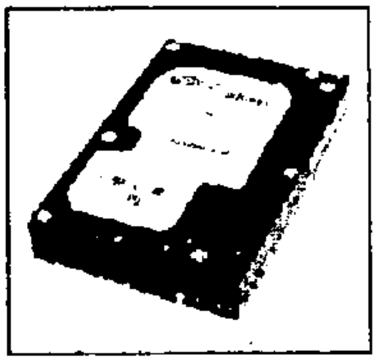
It is located near the central hole. It is used to identify the starting position of the track.

**4) Read / Write Hole:**

With the help of this hole, the disc drive head can read and write the data. The data is stored on about 2cm strip of the disc. Floppy disc can store about 1.44 mega bite data.

**Q15: Write a note on hard disc.**

Ans. **Hard Disc:**



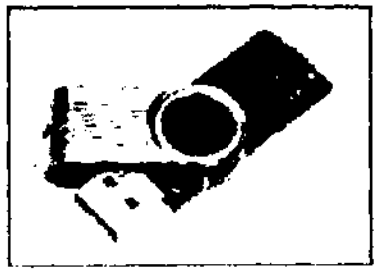
It is a storage device which is installed inside the system unit. It is hard and non-flexible because it is made from aluminum. It is coated with ferromagnetic material, so it can be magnetized very easily. The hard disc posses high speed and can store large amount of data as compare to other disc. The disc revolves about a specific axis inside a box. It is enclosed in a jacket to protect it from external bad effects. Using this disc and by a control board, a large number of information can be read and written.

**Q16: Write a note on flash drive.**

Ans. **Flash drive (or) Universal Serial Bus [USB]:**

The USB is another storage device, which is

smaller in size as compare to other storage devices. It is removable and rewritable. We can transfer data from one place to another through USB easily. We can also store music, movies and pictures in USB.



**Q17: Write a note on word processing.**

Ans. **Word Processing:**

We can type a word with the help of keyboard by using word processing programme. We can make any correction while composing certain documents. After composing, we can save the documents for future use. We can also take a copy of the documents with the help of printer. The saved documents can also be transfer to other computers by storage devices, internet or by email very easily.

**Q18: Write a note on graphic designing.**

Ans. **Graphic Designing:**

The graphic designing is a computer programme with the help of which we can design graphics, brochures, newsletters, visiting cards, signs boards, flex board and any other type of visual communication. It makes the text and graphic more attractive and effective.

**Q19: Write a note on data managing.**

Ans. **Data Managing:**

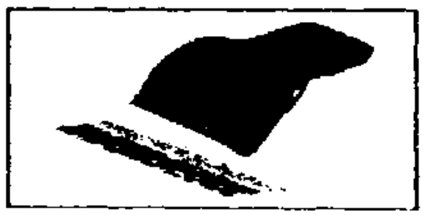
Data base is the bank of data or information which can be stored in a file. Each file has its own name, address and other identifications. With the help of data base managing program, we can search for any data in any data base file very quickly and easily. We can change the documents of any time very easily. The data managing program can be used for recording the price of various items in business centers.

**Q20: Write a note on monitoring and control.**

Ans. **Monitoring and Control:**

In big stores and super markets, the optical scanners are used with the help of laser beam, to read the bar codes of a product which indicates the number at which this product is recorded in the register.

6 7 1 8 6 0 0 1 3 6 2 4



In this way, the detail about its price is obtained. It also helps placing the order for goods being sold in a large quantity and to decide about less selling goods.

## Exercise

**Q1: Choose the correct answer.**

1. The components of information and communication systems are humans, hardware, software, procedures and.........
   a. Computers
   b. Fields
   c. Signals
   **d. Data/ information✓**
2. Electric or electromagnetic representations of data or information is termed s:
   a. Computer
   **b. Signal✓**
   c. Transmission
   d. Software
3. The phenomenon of total internal reflection is used in transmission of signal through......
   a. Electric wires
   **b. Optical fibers✓**
   c. Electromagnetic waves
   d. Radio
4. Electrical conductor or system of conductors used either for radiating electromagnetic energy or for collecting electromagnetic energy is....
   **a. Antenna✓**

b. Satellite
c. Repeater
d. Signal

5. Software that allows users to interact with the computer system is:
a. Hardware
b. Application
**c. Operating system✓**
d. Program

6. Which of the following information storage device has no moving parts to store and retrieve information?
a. CD/DVD
b. Hard drive
**b. Flash drive✓**
d. Floppy

7. Which of the following information storage device is least used these days?
a. CD/DVD b. Hard drive
c. Flash drive **d. Floppy✓**

8. Telephone communication is the example of transmission of signals through......
a. Electric wires
b. Optical fibers
c. Electromagnetic waves
**a. All of these✓**

## Conceptual Questions

**Give a brief response to the following questions:**

**Q1: Identify the most reliable means of storing information.**

Ans. The most reliable means of storing information are hard drive, USB or flash drive, CD and DVD.

**Reasons and Explanation:**

A storage device is a physical piece of hardware that is used to store data. In most cases, any type of file can be added to a storage device. The following are in common use:

**(1) Hard drive:**

Inside the hard drive is a physical disc (referred to as a platter) that spins constantly. Hard drives will vary in performance, most of which is based on the speed of the disc.

**(2) USB flash drive:**

USB flash drives are small, portable storage devices that are most commonly used for transferring data from one computer to another. USB flash devices are protected by a shell casing, which makes them more reliable when they are transported.

**(3) CD and DVD:**

These are circular discs on which data is stored on one or both sides, they are made of very

strong plastic material. These are a reliable sources of storing information. These discs are used in our everyday lives for storage, backing up photos, movies, music and much more.

**Q2: How information is different from data?**

Ans. Information is different from data.

**Reasons and Explanation:**

1. **Data:**

Data is the collection of facts and figures. It is raw, un-organized facts that need to be processed. Data is given to computer through input device. The computer process the data internally and then gives us information in the light of given data.

2. **Information:**

When data is processed internally by computer such that it becomes useful and meaningful for user, then it is called information. Information gives organized knowledge to the users. When the data is processed in central processing unit of computers, then we get information from the processed data. We can see the information on output device like monitor or printer etc.

**Q3: Why frequency band for uplink and down-link is different in transmission of microwaves through space?**

Ans. The frequency band for uplink and down-

link is different in transmission of microwaves through space.

**Reasons and Explanation:**

If the frequency band for the uplink and down-link be same, then there are chances of interference between the transmitted signals from the ground station and receiving signals from satellite. This interference causes disturbance in signals. In order to avoid the chances of interference in signals the uplink frequency is kept higher than the downlink frequency.

**Q4: What does cell in "cell phone" refer to?**

Ans. The word "cell" means the area around the tower in which the signals from the mobile can be transmitted and received. The mobile phone is wireless phone which receive the signals from the tower. The mobile phone work only when it is in the range of a tower i.e. in the cell of tower, therefore mobile phone called cell phone.

**Q5: Can internet be used for shopping. Give an example.**

Ans. Yes, internet is widely used for online shopping in the world. In online shopping a consumer directly buy goods or services from a seller using a web browser. Consumers find a product of internet by visiting the website of

the retailer· Consumers can buy from almost everything of his / her daily use to most sophistical and expensive equipments and devices· A typical online store enables the customer to house the firms range of products and services, view information, photos and images of the products, their prices etc·

**Q6: How a flash drive is different from other storage devices?**

Ans·

1· Flash drive is smaller in size than other storage devices like DVD and hard disk·
2· It can be remove from computer easily as compare to other storage device like hard disk·
3· The user can shift it from one place to another easily·
4· It can be scan easily·
5· We can transfer various record files in flash drive easily·
6· It has no moving parts like other storage devices·

## Comprehensive Questions

Given an extended response to the following questions:

1. What is information and communication technology (ICT)? Explain briefly its components.

Ans. See answer of question number 2 in the text.

2. Explain the flow of information. Describe how information is transmitted as electric signal through wires, light signals through optical fibers and radio waves through air / vacuum?

Ans. See answer of question number 3 in the text.

3. Describe function and use of fax machine, cell phone, photo phone and computer.

Ans. See answer of question number 6, 7, 8, 9 in the text.

4. What is email and internet? List few uses of internet in daily life.

Ans. See answer of question number 10, 11 in the text.

5. What are information storage devices? Describe the use of information storage devices

such as audio cassettes, video cassettes, hard discs, floppy compact discs and flash drive?

Ans. See answer of question number 12, 13, 14, 15, 16 in the text.

6. What are the functions of word processing?

Ans. See answer of question number 17 in the text.

7. How information is handled? Describe data management and its monitoring and control?

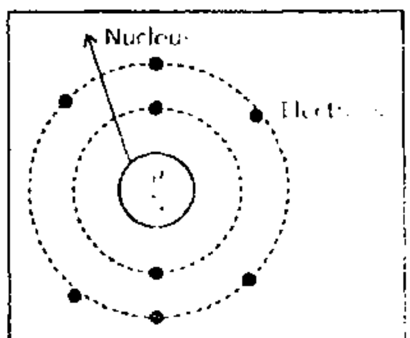
Ans. See answer of question number 18, 19, 20 in the text.

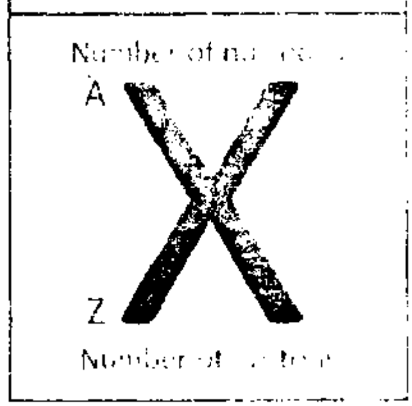
CHAPTER 18

# NUCLEAR PHYSICS

**Q1: What is nucleus? How a nuclide is represented symbolically?** نیوکلیئس کیا ہوتا ہے نیوکلیائیڈ کو علامتی طور پر کیسے ظاہر کرتے ہیں؟

Ans: The atom consists of two parts. The central part is called nucleus which consist of protons and neutrons. The outer part consists of circular orbits in which the electrons revolves around the nucleus. The nucleus is spherical in shape. Its diameter is about $10^{-14}$ m and the diameter of atom is $10^{-10}$ m.






The number of protons and neutrons inside the nucleus are called nucleons. The mass of proton is $1.67 \times 10^{-27}$ kg and its charge is $1.6 \times 10^{-19}$ coulomb. The neutron is chargless particle. Its mass is slightly less than the mass of proton.

The mass of electron is $9.1 \times 10^{[illegible]}$ kg and its charge is $1.6 \times 10^{[illegible]}$ coulomb. under normal conditions. the number of electrons and proton are equal. So as a whole the atoms posses no net

charge.

The number of protons inside the nucleus is called atomic number. It is represented by "z". The number of neutrons are represented by "N". The number of protons and neucrons is called mass number. It is represented by "A".

Generally an element "X" with number of nucleon "A" and number of protons "Z" in represented by "$^{A}_{Z}X$".

The number of neutrons "N" can be calculated by subtracting "Z" from "A". i.e. $\boxed{N = A - Z}$

In case of neutral atom, the number of protons and electrons are same. The number of neutrons may be same to the protons or may be different. If an atom posses same number of protons and neutrons, then the nuclei of such atoms is known as nuclides.

**Q2: What is radioactivity? Give the nature, ionizing and penetrating abilities of the three types of radioactive emissions?**

تابکاری سے کیا مراد ہے۔ تابکار شعاعوں کی نوعیت، آئیونائزیشن اور نفوذ کی طاقت پر بحث کریں؟

Ans: Radioactivity [تابکاری]: (BISE Mardan, Swat, Malakand 2019)

The phenomenon in which certain elements emit radiations without any ∈ ternal help is known as natural radio-activity.

Explanation [وضاحت]:

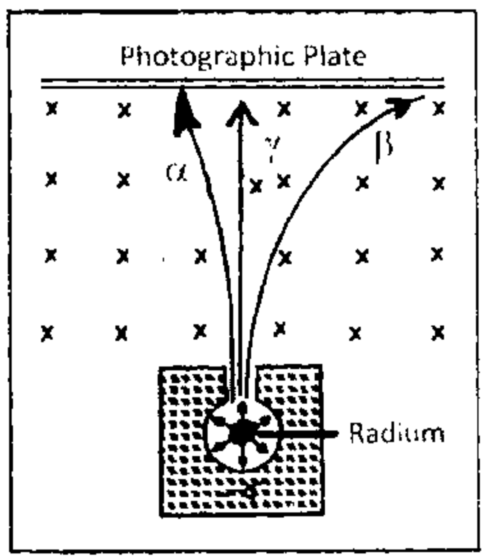
The phenomenon of radioactivity was first observed by French scientist Prof. Henry Becqural in 1896.

He took pure specimen of uranium salt and examines it in the presence as well as in the absence of sunlight. In both cases, it was found that the uranium specimen emits radiations. This shows that radioactive elements emit radiations without any external help.

Then in 1899, Rutherford showed that the radioactive elements emits "α" and "β" rays.

Then in 1909, Villard showed that these elements also emit γ-rays. For this purpose he performed the following experiment.

Experiment [-ϗ]:




In this experiment, a piece of radioactive element (radium) was placed at the bottom of the lead, as shown in the figure.

The radiations emitted by "radium" were allowed to enter in a vacuum chamber in which a uniform magnetic field was applied. As soon as these radiations enter the magnetic field, they were deflected and gave three images on the photographic plate.

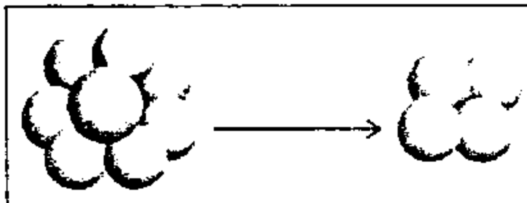
| |
|---|
| ∝ → alpha |
| β → beta |
| γ → Gamma |

The radiations which were deflected towards right are known as β − rays. The radiations which were deflected towards left are known as α − rays.

While the radiations which were passed undeflected, are known as $\gamma$ – ras.

Properties of Alpha Rays [الفا شعاعوں کی خصوصیات]:

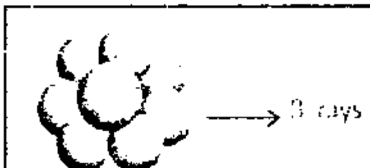
1. These are doubly charged positive rays.
2. These rays can be deflected by magnetic and electric fields.
3. They have low penetrating power due to their heavier masses and low velocity.


Emission of alpha particle from nucleus

4. They have high ionization power due to their low velocity.
5. They can produce fluorescence when strike on a screen.
6. They can produce artificial radio activity in certain substances.
7. They scattered through large angle from certain substances.
8. They produce burn when exposed to human body.

Properties of Beta Rays [بیٹا شعاعوں کی خصوصیات]:

1. They are negatively charged particles.
2. They can be deflected by magnetic and electric fields.



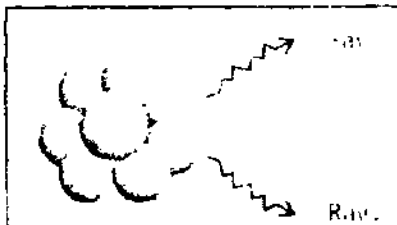
Emission of beta particle from nucleus

3. They have high penetrating power due to their lighter masses and high velocity.

4. They have low ionization effect due to their high velocity.
5. They can produce fluorescence when strike on a screen.
6. Their velocity is greater than velocity of $\alpha$ - rays.

Properties of Gamma Rays [گیما شعاعوں کی خصوصیات]:

1. These are neutral rays.
2. They can pass through electric and magnetic field undeflected.
3. They have very high penetrating power.

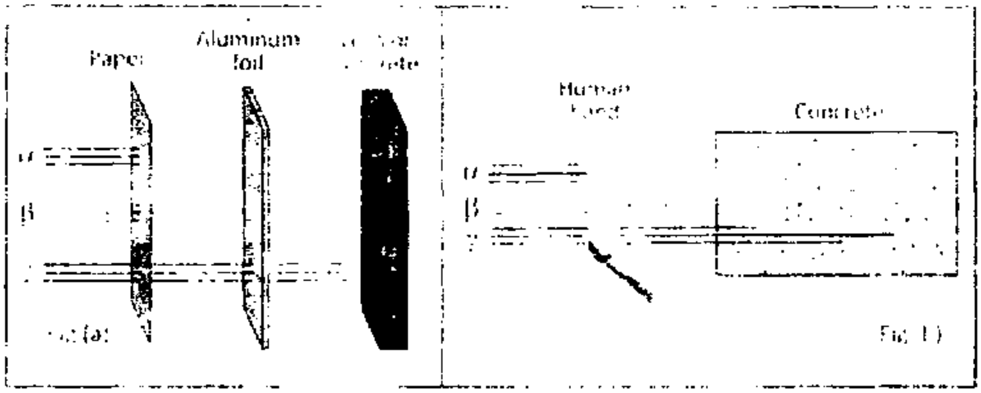


Emission of gamma rays from nucleus

4. They have very high velocity i,e they travel with velocity of light.
5. They have very low ionization power.
6. They can produce fluorescence when they strike on a screen.

1. Relative Ionizing abilities: The phenomena by which radiation can split matter into positive and negative ions is called ionization. All the three types of radiation (alpha '$\alpha$' beta '$\beta$' and gamma '$\gamma$') have quite different ionizing abilities in air. Alpha ($\alpha$) particles ionize air much strongly due to its large mass and charge than beta ($\beta$) and gamma ($\gamma$) radiations. Gamma radiation has the least ionizing ability as compared to alpha '$\alpha$' and beta '$\beta$' radiations.

2. Relative Penetration abilities: Penetrating ability is how deeply a radiation can go into a material. All the three types of radiation (alpha 'α', beta 'β' and gamma 'γ') have quite different penetrating abilities as well. Alpha particles barely penetrate a sheet of paper and has range of no more than a few centimeters in air. Beta particles can penetrate a few millimeters of aluminum. It has range in air of about 1m. Gamma rays can penetrate several centimeters of lead and has an infinite range in air as shown in figure (a).




In figure (b), it is shown that α -particles can be easily absorbed by our hand, where as beta and gamma will pass through. Beta radiations on the other hand will be easily stopped by concrete block whereas gamma will travel few centimeters before being absorbed in concrete.

**Q3: Radioactive sources are said to have half life. What is the meaning of half life?**

تابکار عناصر کے نصف حیات ہوتی ہے۔ نصف حیات سے کیا مراد ہے؟

Ans. Half Life [نصف حیات]:

(BISE Bannu, Kohat, Peshawar 2019)

The time in which half of the atoms in any ra-

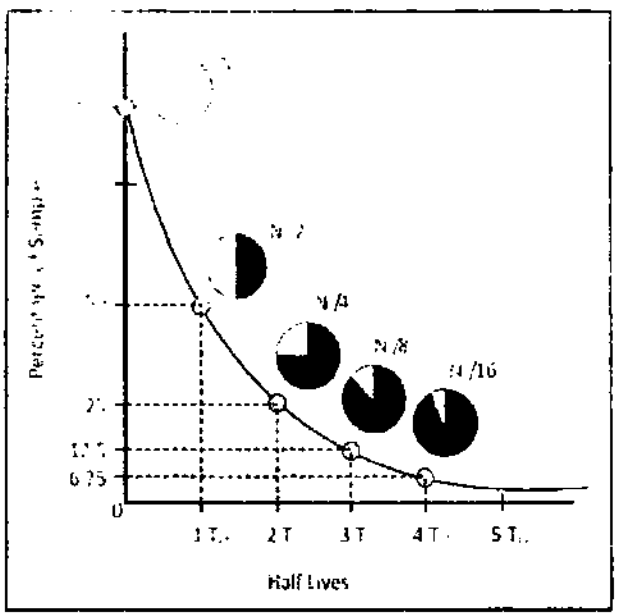
dioactive element, decay into daughter element in known as half life.

Explanation:

We know that any radioactive element emits radiations. The passage of time this radioactive element changes into another element. The original element is known as parent element [مورثی عنصر] while the new element is known as daughter element [دختری عنصر].

Now during this process, a stage comes when half atoms of parent element decays into daughter element. The time interval taken during this process is known as half life.

For example, if there are 20000 atoms in parent element, then after half life 10000 atoms will decay into daughter element.




Let N represent the amount of the original sample remaining after any given time interval "Δt" and "$N_o$" represent the original amount in the sample given in the same units as "N" Then

After 1 half-life, $N = \frac{1}{2} N_o$

After 2 half-live,

$$N = \frac{1}{2} \times \frac{1}{2} N_o = \left(\frac{1}{2}\right)^2 N_o$$

*After 3 half-lives,* $N = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} N_o = \left(\frac{1}{2}\right)^3 N_o$

*Generally* $$N = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} \cdots N_o = \left(\frac{1}{2}\right)^n N_o \quad \text{............(1)}$$

*Using equation (1), we can calculate the amount of sample remaining after given time interval.*
*Where, the number 'n' of half-lives is equal to the time interval ($\Delta t$) divided by the time for one half-life ($T_{1/2}$).*

$$n = \frac{\Delta t}{T_{\frac{1}{2}}} \quad \text{..................(2)}$$

*Different materials have different half lives which ranges from $10^{10}$ years to a fraction of second. Half lives of some common radioisotopes are shown in table.*

**Table 18.2 Half lives of some common radioisotopes**

| Radioisotopes | Decay | Half life |
|---|---|---|
| Beryllium-8 | α | $2.0 \times 10^{-10}$ s |
| Polonium | α | $1.64 \times 10^{-4}$ s |
| Iodine-131 | β | 8.04 d |
| Cobalt-60 | β | 5.3 y |
| Radium-226 | α | $1.62 \times 10^{3}$ y |
| Carbon-14 | β | $5.73 \times 10^{3}$ y |
| Uranium-235 | α | $7.04 \times 10^{8}$ y |
| Uranium-238 | α | $4.45 \times 10^{9}$ y |

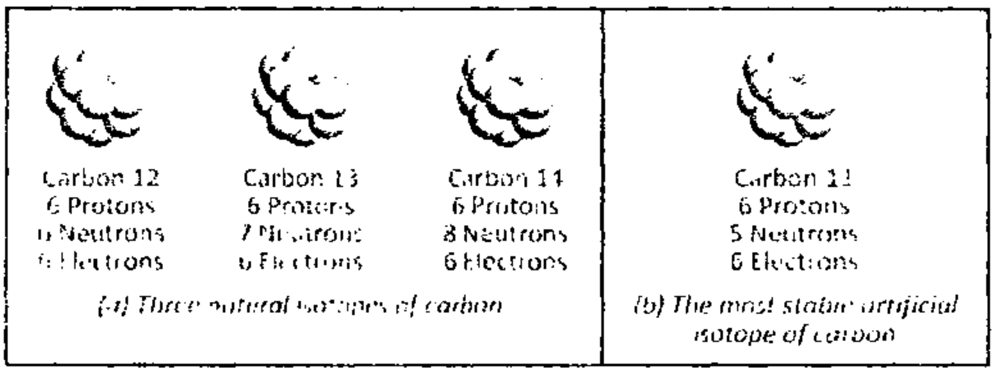
*Q4: What are isotopes? Discuss the uses of radio isotopes?*

*Ans. Isotopes: (BISE Peshawar, Mardan 2019)*

*The atoms of an element having same atomic number but different mass number are known as isotopes. For example, the isotopes of hydrogen are, protium "$_1H^1$", deuterium "$_1H^2$" and tritium "$_1H^3$".*

*Radio Isotopes [تابکار آئسوٹوپس]:*

*The isotopes of radioactive elements are called radioisotopes. Carbon is the most abundant element in earth atmosphere, $C^{12}$, $C^{13}$, $C^{14}$ are the three natural isotopes of carbon. $C^{11}$ is the artificial isotope of carbon.*




(a) Three natural isotopes of carbon

(b) The most stable artificial isotope of carbon

*Fluorine, sodium, aluminum, phosphorous and gold consists of only one stable isotopes.*

*Uses of Radio Isotopes [تابکار آئسوٹوپس کا استعمال]:*

*We know that radioactive isotopes emits radiations. These radiations can be used in the following departments for various purposes.*

*(1) Medicine: In medicines, the radio isotopes can be use for the following purposes.*

*1. Cobalt-60 is radio isotope which is used for*

the treatment of cancer.

2. Iodine-131 is radio isotope which is used for the study of thyroid glands.
3. Phosphorous-32 is radio isotope which is used to locate the exact position of tumor in the brain.
4. Radio sodium is used for tracing blood circulation in human body.
5. Radio strontium is use for the treatment of wounds.
6. Radio isotopes are used to study the effects of medicine on human body.
7. Radio isotopes are used for cleaning of surgical instrument.

2. Uses of Radio Isotopes in Industry:

1. The radio isotopes can be use to estimate the wear and tear of the machine tools.
2. They are used in industry for checking the thickness of materials.
3. They are used to detect cracks in welded joints.
4. They are used to detect leakage in pipes.

3. Uses of Radio Isotopes in Agriculture:

1. They are used to kill bacteria to preserve food stuff.
2. They are used to protect seeds from various insetts.
3. They are used to increase the fertility of soil.

**Q5: What are nuclear transmutations? What changes in the composition of the nucleus is observed when alpha or beta particles are emitted. Explain by symbolic equations?**

Ans. **Nuclear Transmutation (or) Nuclear Decay:**
The process through which an unstable nucleus (parent nucleus) transforms into a more stable nuclide (daughter nucleus) is called nuclear transmutation or nuclear decay.

1. **Alpha decay:** In case of alpha decay the parent nuclide is converted into daughter nuclide whose charge number 'Z' is two less and mass number 'A' is four less than parent nuclide. The symbolic equation is given,

$$ {}_{Z}X^{A} = {}_{Z-2}Y^{A-4} + \alpha + Q \quad \text{............(1)} $$

In eq (1), 'X' represent parent nuclide, 'y' represent daughter nuclide and 'Q' represent the energy released in the process.

Example:

$$ {}_{92}U^{238} = {}_{90}Th^{234} + {}_{2}He^{4}(\alpha - \text{particle}) + Q $$

2. **Beta decay:** In case of β-decay, the parent nuclide is converted into daughter nuclide whose charge number is one greater and mass number remain to that of parent nuclide. The symbolic equation is given by,

$$ {}_{Z}X^{A} = {}_{Z+1}Y^{A} + \beta + Q \quad \text{............(2)} $$

Example:

$$ {}_{90}Th^{234} = {}_{91}Pa^{234} + \bar{\beta} + Q $$

**Q6: How carbon-14 used to determine the ages of wood, bones and other artifacts? (OR) explain radioactive dating?**

Ans. Radioactive Dating:

Archaeologists and geologists use radioactive dating to estimate the age of ancient objects. One common procedure uses carbon-14 which has a half-life of 5730 years. As long as the creature is alive, it will continue to absorb and collect carbon-14. Once the creature dies, no further carbon-14 will be ingested, and the proportion of carbon-14 will start to decline.

The proportion of the total amount of carbon that is carbon-14 is very small. A measurement of the activity present can therefore be used to estimate the age of the specimen. Carbon-14 dating can be used for biological tissues as old as 50 or 60 thousand years, but is most accurate for younger samples, since the abundance of $^{14}C$ nuclei in them is greater. Very old biological materials contain no $^{14}C$ at all.

Materials with relatively longer half-lives can be used to determine the age of geologic formations. Uranium-238, for example, with a half-life of $4.53 \times 10^{9}$ years, can be used to date even the oldest deposits on Earth.

**Q7: Explain Einstein Mass-Energy relations.**

Ans. The relation b/w mass and energy was obtained by Einstein in 1905. This relation is given by;

$$E = mc^2 \quad \text{...........(1)}$$

In equation (1) "E" represents the energy, "m" represents the mass and "C' represents the velocity of light.

Equation (1) shows that "mass" and "energy" are inter-convertible.

**Q8: State and explain nuclear fission.**
نیوکلیائی انشقاق کی تعریف اور وضاحت کریں؟

*Ans.* Definition: (BISE Peshawar, Kohat 2019)

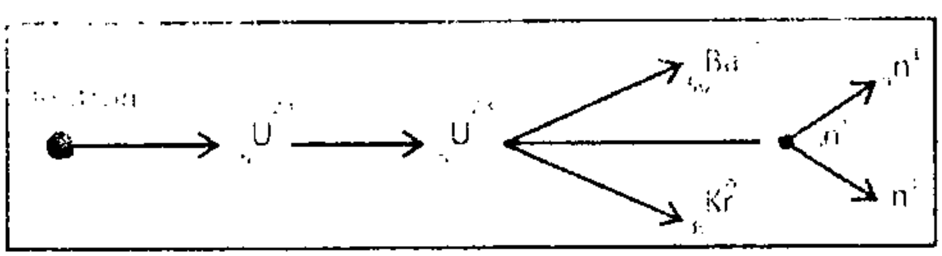
It is a special type of nuclear reaction in which a heavy nucleus splits up into two nuclei with the release of huge amount of energy.

Explanation:

The process of fission was first discovered by Hahn and Fritz in 1938.

This process can be produced, when sufficient energy is supplied to target nucleus by bombarding neutron, or proton or $\gamma$ rays etc. But the most useful method is the bombardment of slow neutron, because the neutron is chargeless particle and they don't experience coulomb's force of repulsion. Thus the neutron can penetrate very far in the target nucleus and can cause nuclear reaction.

Example of fission: Consider a slow neutron is allowed to [illegible] uranium "[illegible]", as shown in the figure.




When the neutron enters into the nucleus of

a compound nucleus is formed. This compound nucleus is unstable and again disintegrate [ ] into two fragments "Ba" and "Kr", with the release of energy.

n + U → U → Ba + Kr + 3 + Energy

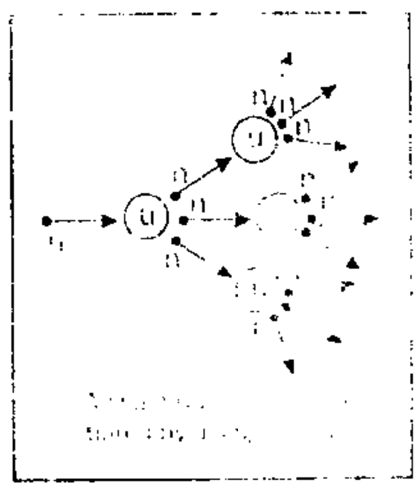
Thus the fission process huge [ ] source of energy.

**Q9: Explain fission chain reaction?**

Ans. Fission Chain Reaction: (BISE Kohat 2019)

We know that when a single neutron is allowed to enter in a target nucleus of U, then a compound nucleus is formed. This compound nucleus is unstable and disintegrates into two fragments "Ba" and "Kr" with the release of huge amount of energy. Three neutrons are also produce in the process.

Now if each one of these neutrons are allowed to produce fission in a given sample of "U", then the number of neutrons released in the process will increase. In this way, a chain reaction will occur which is called fission chain reaction.



In fission chain reaction, huge amount of energy is released which cause violent explosion and destroy everything that comes in its path. The explosion of atom bomb is based on fission chain reaction.

For fission chain reaction, the mass of uranium should be greater than some minimum mass which is called critical mass. Thus fission chain reaction can be controlled by using very small amount of uranium.

**Q10: Explain nuclear fusion process. عمل ایتلاف کی وضاحت کریں؟**

Ans. Definition:

It is a type of nuclear reaction in which two or more than two lighter nuclei combine together and form an intermediate nucleus with the emission of large amount of energy.

Explanation:

It is the reverse process of nuclear fission. In 1920, Edington gave the correct idea about the energy released from the sun and other stars. He told that in "sun" and other stars, the protons are converted into Helium nucleus. This idea was confired in 1939.

The atoms in stars are completely ionized at very high temperature. Due to this highest temperature, their K.E increases and they move with high speed. Thus the two nuclei become able to overcome the coulombs force of repulsion and thus they fused together and form an intermediate nucleus. Such reaction is also known as thermo nuclear reactions.

Example of Nuclear Fusion:

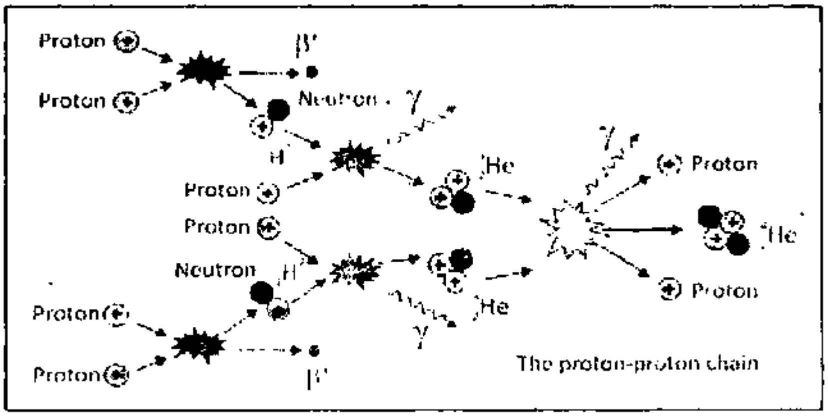
Proton-proton cycle: During fusion reactions on sun and other stars, four protons combine and form Helium nucleus. But the combination of four protons in a single step is not possible due to coulombs force of repulsion. These protons combine in number of steps to form "$_2He^3$" nuclei. Finally two "$_2He^3$" nuclei

combine and form Helium nucleus.

<u>Step (1):</u> $_1H^1 + _1H^1 \longrightarrow _1H^2 + \beta^+$

<u>Step (2):</u> $_1H^1 + _1H^2 \longrightarrow _2He^3 + \gamma$

<u>Step (3):</u> $_2He^3 + _2He^3 \longrightarrow _2He^4 + _1H^1 + _1H^1 + \gamma$




**Q11: What are background radiations? What are its major sources?**

Ans. <u>Background Radiation:</u>

All living creatures, from the beginning of time, have been and are still being exposed to radiation. When a radiation detector is used it will record these radiations called natural background radiation, it comes from three sources:

1. <u>Cosmic Radiation:</u> The earth and all living things on it, are constantly bombarded by radiations from space. The dose from cosmic radiation varies in different parts of the world due to differences in elevation and to the effects of the earth's magnetic field.

2. <u>Terrestrial Radiation:</u> Radioactive material is also found throughout nature. It is in the soil, water and vegetation. Low levels of uranium, thorium, and their decay products are found everywhere. The

dose from terrestrial sources also varies in different parts of the world.

3. Internal Radiation: All people also have radioactive potassium-40, carbon-14, lead-210, and other isotopes inside their bodies from birth.

**Q12: Explain nuclear reactor?** نیوکلیئر ریئکٹر کی وضاحت کریں۔

Ans. Definition:

It is a machine in which nuclear fission is produced for the production of nuclear energy.

Construction [ساخت]:

The nuclear reactor consists of the following parts.

i. Fuel [ایندھن]: $_{92}U^{235}$ in the form of rods is used as a fuel.

ii. Moderator [ثالث یا تقلیل گر]: With the help of moderator fast neutrons produced in the fission, are slowed down because slow neutron is more efficient to produce fission. For this purpose heavy water is used to moderate the speed of fast neutrons.

iii. Neutron absorber [نیوٹران جاذب]: The boron rods are used to absorb excess neutrons so that the fission may be produced in a controlled manner.

iv. Coolant [ٹھنڈا کار]: The fuel rods, neutron absorbers and moderator are collectively known as "core of the reactor".

The coolant is used to cool down the core. For this purpose, the coolant absorbs heat energy from the core and transfers it to a boiler where the heat is converted into steam. This steam is used to run a turbine for generation of electricity.

**Q13: What are radiation hazards? How can we safeguard ourselves from radiations? (OR) Discuss the harmful effects of radiations. How can we protect against these radiations?**

Ans. Harmful Effects of Radiations:

1. The nuclear radiations can damage our body cells.
2. The nuclear radiations can cause cancer diseases.
3. The nuclear radiations can produce incurable burn.
4. The nuclear radiations can effect our eye sight.

Precautions against Nuclear Radiations:

1. We should stay away from radioactive source, because these radiations spread in all directions.
2. The doctors should use the radiations for minimum possible time during the treatment.
3. Over dose of radiations should be avoided.
4. The nuclear waste should be buried far away from the residential areas.
5. We should build a thick wall of concrete around the reactor to protect ourselves from radiations.
6. We should place the radioactive material in a box of lead.
7. We should use film badge and dosimeter during the determination of intensity of radiations.
8. The person should check themselves medically on regular basis who is working in nuclear laboratory.

۞ جب تم سالن پکاؤ تو اس میں سے پانی ذرہ ذرہ ڈال دو اور اپنے ہمسایہ کو بھی اس میں ایک دو چمچہ دے دو۔ (حضور اکرم ﷺ)

## Solution of Examples, Assignments

**Example 1:** An unstable polonium 218 ($^{218}_{84}Po$) atom spontaneously emits an alpha ($\alpha$) particle and transmutes into an atom of some other element. Show the process, including the new element, in standard nuclear reaction notation.

Solution:

Given data:

The $\alpha$ − decay for any nuclide is given by,

$$_{Z}X^{A} = {}_{Z-2}Y^{A-4} + \alpha + Q \text{ ________ } (1)$$

Replaced $_{Z}X^{A}$ by $_{84}Po^{218}$ in equation (1), we get,

$$_{84}Po^{218} = {}_{84-2}Y^{218-4} + \alpha + Q$$

(OR) $_{84}Po^{218} = {}_{82}Y^{214} + \alpha + Q$ ________ (2)

Now the element having (z = 82) and (A = 214) in periodic table is lead ($_{82}Pb^{214}$), so replaced $_{82}Y^{214}$ by $_{82}Pb^{214}$ in equation (2), we get,

$$\boxed{_{84}Po^{218} = {}_{82}Pb^{214} + \alpha + Q} \text{ ______ } (3)$$

So when $_{84}Po^{218}$ undergo $\alpha$ − emission, it is converted into $_{82}Pb^{214}$

**Assignment 1:** Find the daughter nucleus when radium -224 undergoes alpha decay.

Solution:

For $\alpha$ − decay, general equation is given by,

$$_{Z}X^{A} = {}_{Z-2}Y^{A-4} + \alpha + Q \text{ ________ } (1)$$

Replaced $_{Z}X^{A}$ by $Ra^{224}$ in equation (1), we get,

$$_{88}Ra^{224} = {}_{88-2}Y^{224-4} + \alpha + Q$$

(OR) $_{88}Ra^{224} = _{86}Y^{220} + \alpha + Q$ ______(2)

Now the element with (Z = 86) and (A = 220) in periodic table is Radon $_{86}Rn^{220}$, so replace $_{86}Y^{220}$ by $_{86}Rn^{220}$ in equation (2), we get,

$$\boxed{_{88}Ra^{224} + _{86}Rn^{220} + \alpha + Q} \quad \text{______(3)}$$

So when $_{88}Ra^{224}$ undergo $\alpha$ – emission, it is converted into $_{86}Rn^{220}$.

**Example 2: The isotope iodine 131 undergoes beta decay. Write the reaction equation, and determine the identity of the daughter nucleus.**

Solution:

The general equation for $\beta$ – emission is given by,

$$_{Z}X^{A} = _{Z+1}Y^{A} + \bar{\beta} + Q \quad \text{________(1)}$$

Replaced $_{Z}X^{A}$ by $_{53}I^{131}$ in equation (1), we get,

$$^{131}_{53}I = ^{131}_{53+1}Y + \bar{\beta} + Q$$

(OR) $^{131}_{53}I = ^{131}_{54}Y + \bar{\beta} + Q$ ________(2)

Now the element with (Z = 54) and (A = 131) in the periodic table is xenon ($^{131}_{54}Xe$), so replaced $^{131}_{54}Y$ by $^{131}_{54}Xe$ in equation (2), we get,

$$\boxed{^{131}_{53}I = ^{131}_{54}Xe + \bar{\beta} + Q} \quad \text{________(3)}$$

Thus when $^{131}_{53}I$ undergo $\beta$ – emission, it is converted into xenon $^{131}_{54}Xe$.

**Assignment 2: An atom of sodium 24 can transmute into an atom of some other element by emitting a beta particle. Represent this reaction in symbols, and identify the daughter element.**

**Solution:**

The general equation for β – decay is given by,

$${}^{A}_{Z}X = {}^{A}_{Z+1}Y + \beta + Q \quad ______(1)$$

Replaced ${}^{A}_{Z}X$ by ${}^{24}_{11}Na$ in equation (1), we get,

$${}^{24}_{11}Na = {}^{24}_{11+1}Y + \bar{\beta} + Q$$

$$\text{(OR)}\quad {}^{24}_{11}Na = {}^{24}_{12}Y + \bar{\beta} + Q \quad ______(2)$$

Now the element with (Z = 12) and (A = 24) in periodic table is magnesium ${}^{24}_{12}Mg$, so replace ${}^{24}_{12}Y$ by ${}^{24}_{12}Mg$ in equation (2), we get,

$${}^{24}_{11}Na = {}^{24}_{12}Mg + \bar{\beta} + Q \quad ______(3)$$

Thus when ${}^{24}_{11}Na$ undergo β – emission, it is converted into ${}^{24}_{12}Mg$.

**Example 3: You have a 160.0 μg sample of polonium 218. It decays by alpha emission with a half life of 3.0 min. How much of the pure sample is left after 9.0 min?**

**Solution:**

**Given data:**

Total quantity of pure polonium -128 = $N_o$ = 160 μg

*Half life of polonium = 218 =* $T_{\frac{1}{2}} = 3{\cdot}0\ min$

*Total elapsed =* $\Delta t = 9\ min$

**Required:**

*Quantity left =* $N = ?$

**Calculation:**

*The number of half lives "n" is given by,*

$$n = \frac{\Delta t}{T_{\frac{1}{2}}} \quad \text{__________(1)}$$

*Putting the values in equation (1), we get,*

$$n = \frac{9{\cdot}0\ \cancel{min}}{3{\cdot}0\ \cancel{min}} = 3$$

*Original sample remaining after any given time interval is given by,*

$$N = \left(\frac{1}{2}\right)^n N_o \quad \text{__________(2)}$$

*Putting the values in equation (ii), we get,*

$$N = \left(\frac{1}{2}\right)^3 x\,160\mu g = \left(\frac{1}{8}x\,160\right)\mu g = 20\mu g$$

$$\Rightarrow \quad \boxed{N = 20\mu g}$$

> *Assignment 3: Lead 210 has a half life of 22·3 years· How much of the 80mg of lead will be left after 66·9 years?*

**Solution:**

**Given data:**

*Half life of lead =* $T_{\frac{1}{2}} = 22{\cdot}3\ years$

*Total quantity of pure lead =* $N_o = 80mg$

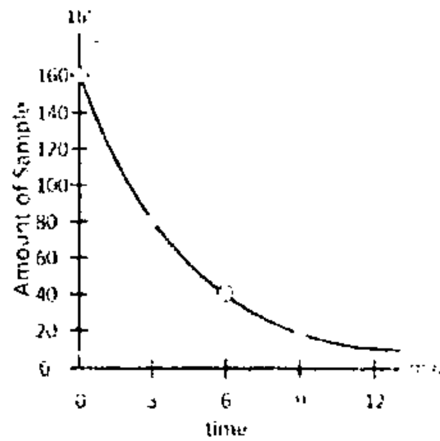
*Total elapsed =* $\Delta t = 66{\cdot}9\ years$

Required: Quantity left = N = ?

Calculation:

We know that remaining sample is given by,

$$N = \left(\frac{1}{2}\right)^n N_o \text{ ——— } (1)$$




First we find the value of "n" for which we have,

$$n = \frac{\Delta t}{T_{1/2}} \text{ ——— } (2)$$

Putting the values of "$\Delta t$" and "$T_{\frac{1}{2}}$" in equation (1), we get

$$n = \frac{66{\cdot}9 \text{ years}}{22{\cdot}3 \text{ years}} \Rightarrow n = 3$$

Putting the values of "n" and "$N_o$" in equation (1), we get,

$$N = \left(\frac{1}{2}\right)^3 x\, 80mg$$

$$= \frac{80mg}{8} = 10mg$$

$$\Rightarrow \boxed{N = 10mg}$$

Assignment 4: Suppose the fossil of bone you are examining has ¼ of carbon 14 deposits as compared to bone of the living animal per gram· The half life of $^{14}C$ is 5730 years, what is the approximate age of the fossil?

Solution:

Given data: Half life = $T_{\frac{1}{2}}$ = 5730 years

Quantity left of carbon $= N = \frac{1}{4} N_o$

*Required:*

Total elapsed $= \Delta t = ?$

*Calculation:*

We know that,

$$n = \frac{\Delta t}{T_{\frac{1}{2}}} \Rightarrow \Delta t = nT_{\frac{1}{2}} ______ (1)$$

We also know that,

$$N = \left(\frac{1}{2}\right)^n N_o ______ (2)$$

Put $N = \frac{1}{4} N_o$ in equation (2), we get,

$$\frac{1}{4} N_o = \left(\frac{1}{2}\right)^n N_o \Rightarrow \frac{1}{4} = \left(\frac{1}{2}\right)^n$$

$$\Rightarrow \left(\frac{1}{2}\right)^2 = \left(\frac{1}{2}\right)^n ______ (3)$$

Comparing the power on both sides of equation (3), we get,

$$2 = n \Rightarrow n = 2$$

Now putting the values of 'n' and $T_{\frac{1}{2}}$ in equation (1)

$$\Delta t = 2 \times 5730 \text{ years}$$

$$\Rightarrow \boxed{\Delta t = 11460 \text{ years}}$$

- ہمسائے سے ملنے والی تکلیفوں پر صبر کرنا بڑے حوصلے کا کام ہے لیکن اس پر اجر عظیم ہے۔
- ہمسائے کا حق یہی نہیں کہ تو اس کو ستائے بلکہ اس کے ساتھ احسان کرنا بھی ضروری ہے۔
- جب موت کا وقت آجاتا ہے تو نہ ہی ایک ساعت پیچھے ہوتا ہے اور نہ ہی ایک ساعت آگے۔
- وقت اللہ تعالیٰ کی امانت ہے جس کا ایک لمحہ بھی ضائع کرنا مجرمانہ خیانت ہے۔

## Exercise

Q1: Choose the correct answer.

1. What is the number of neutrons in the plutonium $^{242}_{92}Pu$?
   a. 92 b. 142
   c. 150✓ d. 242
2. Which one or more the three decay processes ($\alpha$, $\beta$ or $\gamma$) results in a new element?
   a. Only $\alpha$ b. Only $\beta$
   c. Only $\gamma$ d. $\alpha$ and $\beta$✓
3. What type of nuclear decay leaves the number of protons and neutrons unchanged?
   a. Alpha decay b. Beta decay
   c. Gamma decay✓ d. Both a & b
4. What type of nuclear decay most often produces the greatest mass and charge loss?
   a. Alpha decay✓ b. Beta decay
   c. Gamma decay d. Both a & b
5. $^{214}_{84}Po$ undergoes $\alpha$-decay to produce a daughter nuclear that itself undergoes $\beta$-decay. Which one of the following nuclei is the one that ultimately results?
   a. $^{211}_{82}Pb$ b. $^{215}_{80}Hg$
   c. $^{211}_{81}Tl$ d. $_{83}Bi^{210}$✓

Solution:

$$_{84}Po^{214} \xrightarrow{\alpha} {}_{82}Pb^{210} \xrightarrow{\beta} {}_{81}Ti^{210}$$

6. Radium 226 decays by emitting an alpha particle. What is the daughter nucleus?

a. Rd b. Rn✓
c. Bi d. Pb

Solution:

$${}_{88}Ra^{226} \longrightarrow {}_{86}Rn^{222}$$

7. $^{39}Ar$ is an isotope with a half life of 269 years. It will reduce to half in:
a. 134.5min b. 134.5 years
c. 269 min d. 269 years✓

8. A sample starts with 1000 radioactive atoms. How many half-lives have elapsed when 750 atoms have decayed?
a. 0.25 b. 1.5
c. 2.0✓ d. 2.5

Solution:

$N_o = 1000$

After 1st half life, $N = \frac{N_o}{2} = \frac{1000}{2} = 500$

After 2nd half life, $N = \frac{500}{2} = 250$

Total atom elapsed = 500 + 250 = 750

Thus 750 atoms will be elapsed in "2" half lives.

9. Origin of energy from the sun and stars is:
a. Fission b. Fusion✓
c. Carbon dating d. Radioactivity

## Conceptual Questions

*Give a brief response to the following questions:*

**Q1: The atomic number of one particular isotope is equal to its mass number. Which isotope is it?**

Ans. The isotope having charge number equal to its mass number is an isotope of hydrogen.

Explanation:

We know that the isotopes of hydrogen are given by,

Isotopes of hydrogen = $_1H^1$, $_1H^2$, $_1H^3$

Here we see that protium "$_1H^1$" is the isotope of hydrogen having same atomic number and same mass number i.e. for $_1H^1$, we have,

Atomic number = Z = 1

And mass number = A = 1

Thus protium "$_1H^1$" is the isotope of hydrogen having atomic number "Z" equal to its mass number "A".

**Q2: Which is the more likely to expose a film kept in a cardboard box, alpha particles or beta particles? Explain.**

Ans. $\beta$ – particle is more likely to expose a film kept in a cardboard box.

Reasons and Explanation:

$\alpha$ - Particle: It is double positively charged particles. Its mass is greater than that of $\beta$–particles. It travels with low speed. It has low penetrating power due to its heavier mass and low velocity. So it cannot penetrate into cardboard to reach the film to expose it.

$\beta$-*Particle:* It is negatively charged particles. It is lighter than $\alpha$-particle. It travels with very high speed as compare to $\alpha$-particle. Due to high speed, the $\beta$- particle posses high penetrating power than $\alpha$-particle. Thus $\beta$-particle can penetrate through the cardboard easily and can reach the film to expose it.

*Conclusion:* Due to high penetrating power, $\beta$-particle will expose the film easily kept in the cardboard box.

**Q3: Is it possible for a form of heavy hydrogen to decay by emitting an alpha particle? Explain.**

Ans. It is not possible for a form of heavy hydrogen to decay by emitting an alpha particle.

*Reasons and Explanation:*

The general form of equation for $\alpha$-decay is given by,

$$_{Z}X^{A} = {}_{Z-2}Y^{A-4} + \alpha + Energy$$

Thus above equation shows that for $\alpha$-decay, the parent nuclide is converted into daughter nuclide whose charge number "Z" is two less and mass number "A" is four less than parent nuclide.

Thus for $\alpha$-decay, the charge number "Z" of parent nuclide must be greater than two and its mass number "A" must be greater than 4. Now we know that deuterium "$_1H^2$" is heavy hydrogen having $Z = 1$ and $A = 2$.

While $\alpha$-particle is "$_2He^4$" having $Z = 2$, and $A = 4$ so $_1H^2$ cannot emit $\alpha$-particle due to its less number of charge number "Z" and mass number "A".

**Q4: Different isotopes of a given element have different masses, but they have the same chemical properties. Explain why chemical properties are unaffected by a change of isotope?**

Ans. The isotopes of a given element have different masses, but they have the same chemical properties.

Reasons and Explanation:

The chemical properties depend upon the charge number "Z" of an element. We know that the isotopes of an element posses same charge number "Z" and different mass number "A".

Thus due to same charge number "Z" all the isotopes of a certain element posses the same chemical properties.

**Q5: What fraction of a radioactive sample has decayed after two half-live have elapsed?**

Ans. After two half-lives 25% of the atoms will decay.

Reasons and Explanation:

Let "$N_o$" represent the original number of atoms. We know that number of un-decayed atoms after n-half lives is given by,

$$N = \left(\frac{1}{2}\right)^n N_o \quad ________(1)$$

For two half lives, we put n = 2 in equation (1), so we get,

$$N = \left(\frac{1}{2}\right)^2 N_o = \frac{N_o}{4}$$

$$\Rightarrow \quad N = \frac{N_o}{4} \quad ______ (2)$$

Now fraction of atoms decay

$$= \frac{\text{number of atom decay}}{\text{original number of atoms}} \times 100$$

$$\Rightarrow \quad \text{Fraction of atoms decay} = \frac{N}{N_o} \times 100\% \quad ____ (3)$$

Putting equation (2) in equation (3), we get,

Fraction of atoms decay

$$= \frac{N_o}{4N_o} \times 100\% = \frac{100}{4}\% = 25\%$$

Thus in two half lives 25% of the atoms will decay.

**Q6: Can carbon-14 dating give the age of fossils dinosaur skeletons? Explain.**

Ans. Carbon-14 dating cannot give the age of fossils dinosaur skeletons.

Reasons and Explanation:

Carbon dating is a technique used to find the age fossils and organic matter. But, this method is only useful for organic matter which is less than 50000 years old. This is because, the amount of C-14 (Which is radioactive) left in an object is too small to be detected after 50000 years.

It is confirmed that the age of dinosaurs is from about 252 million years to 66 million years, known as Mesozoic Era. Therefore, it is not possible to determine the age of dinosaurs using C-14 dating.

*Q7: Some food is treated with gamma radiation to kill bacteria. Why is there not a concern that people who eat such food might be consuming food containing gamma radiations?*

Ans. Food through which gammas radiations are passed is not harmful for human beings.

Reasons and Explanation:

The gamma radiation is electromagnetic wave of very high frequency and high penetrating power. When the fruits are packed, then these packed fruits are passed through gamma radiation, which kill bacteria and insects by increasing its time of preservation. But due to high penetrating power the gamma radiation penetrate from fruit and cannot stored in it. Therefore the person eating the fruit will not be affected from gamma radiation.

*Q8: Radioactive alpha emitters are relatively harmless outside the body, but can be dangerous if ingested or inhaled?*

Ans. Radioactive alpha emitters are relatively harmless outside the body, but can be dangerous if ingested or inhaled.

Reasons and Explanation:

Alpha particles are double positively charged particles. They are massive than $\beta$−particles and $\gamma$−rays. They have low velocity and less penetrating power. So it is less dangerous when present outside of our body. But if it is ingested or inhaled, it cause serious problems in our body. It can damage

our body cells, tissues and bones due to their high ionization effect. For example, it can cause lungs cancer.

**Q9: If nuclear radiation is harmful, how it can be used for treatment of diseases?**

Ans. The nuclear radiation is harmful but still we can use them for treatment of various diseases.

Reasons and Explanation:

The nuclear radiations are used for the treatment of various diseases. But when these radiations are exposed to human body, they may cause severe burns and other diseases. To avoid such harmful effects, there radiation should be used carefully by expert doctors. The radiations should be focused on the germs of affected area and other healthy parts of the body should kept safe and sound from falling of radioactive radiations.

## Comprehensive Questions

Given an extended response to the following questions:

**1. What is nucleus? How a nuclide is represented symbolically?**

Ans. See answer of question no 1 in the text.

**2. What is radioactivity? Give the nature, ionizing and penetration abilities of the three types of radioactive emissions.**

Ans. See answer of question no 2 in the text.

Total elapsed = $\Delta t = 24$ days

**Required:**

Quantity left = $N$ = ?

**Calculation:**

We know that,

$$N = \left(\frac{1}{2}\right)^n N_o \text{ ________ (1)}$$

For finding 'n', we have

$$n = \frac{\Delta t}{T_{\frac{1}{2}}} = \frac{24 \text{ days}}{8{\cdot}02 \text{ days}} \Rightarrow n = 2{\cdot}99 = 3$$

Now putting the values of 'n' and '$N_o$' in equation (1), we get,

$$N = \left(\frac{1}{2}\right)^3 \times 100gm = \frac{100}{8} gm = 12{\cdot}5gm$$

$\Rightarrow$ $N = 12{\cdot}5gm$

$\boxed{N = 12{\cdot}5gm}$ Ans·

**Q5: Phosphorus 32 is used in plant sciences for tracking a plant's uptake of fertilizer from the roots to the leaves· The half life of $^{32}P$ is 15 days· Out of 800μg of the activity given as fertilizer how much will be left after one month?**

**Solution:**

**Given data:**

Half life of phosphorus = $T_{1/2}$ = 15 days

Total quantity = $N_o$ = 800μg

Total elapsed = $\Delta t$ = 1 month = 30 days

**Required:**

Quantity left = N = ?

**Calculation:**

We know that,

$$N = \left(\frac{1}{2}\right)^n N_o \quad \text{__________}(1)$$

For finding 'n', we have,

$$n = \frac{\Delta t}{T_{\frac{1}{2}}} = \frac{30\ days}{15\ days} = 2$$

Putting the values of 'n' and '$N_o$' in equation (1), we get,

$$N = \left(\frac{1}{2}\right)^2 x\, 800\mu g = \frac{1}{4} x\, 800\mu g$$

$\Rightarrow$ $N = 200\mu g$

$$\boxed{N = 200\mu g} \text{ Ans.}$$

**Q6:** $^{12}C$ to $^{14}C$ ratio in an animal fossil is found to be one fourth of the ratio in the bone of living animal. The half life of $^{14}C$ is 5730 years, how old is the fossil?

**Solution:**

**Given data:**

Half life = $T_{\frac{1}{2}}$ = 5730 days

Quantity left of carbon = $N = \frac{1}{4} N_o$

***Required:***

*Total elapsed* $= \Delta t = ?$

***Calculation:***

*We know that,*

$$n = \frac{\Delta t}{T_{\frac{1}{2}}} \Rightarrow \Delta t = nT_{\frac{1}{2}} \quad \text{________}(1)$$

*We also know that,*

$$N = \left(\frac{1}{2}\right)^n N_o \quad \text{________}(2)$$

*Put* $N = \frac{1}{4}N_o$ *in equation (2), we get,*

$$\frac{1}{4}N_o = \left(\frac{1}{2}\right)^n N_o \Rightarrow \frac{1}{4} = \left(\frac{1}{2}\right)^n$$

$$\Rightarrow \left(\frac{1}{2}\right)^2 = \left(\frac{1}{2}\right)^n \quad \text{________}(3)$$

*Comparing the powers on both sides of equation (3), we get,*

$$2 = n \Rightarrow n = 2$$

*Now putting the values of 'n' and '*$T_{\frac{1}{2}}$*' in equation (1), we get,*

$$\Delta t = 2 \times 5730 \text{ years} = 11460 \text{ years}$$

$$\boxed{\Delta t = 11460 \text{ years}} \text{ Ans.}$$

OOO

# Collection of Important Formulas

| | | |
|---|---|---|
| 1. | $T = 2\pi\sqrt{\frac{m}{k}}$ | [Time period of mass-spring system] |
| 2. | $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$ | [Frequency of mass-spring system] |
| 3. | $T = 2\pi\sqrt{\frac{\ell}{g}}$ | [Time period of simple pendulum] |
| 4. | $f = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}}$ | [Frequency of simple pendulum] |
| 5. | $F = kx$ | [Hook's law] |
| 6. | $v = f\lambda$ | [Relation between frequency, wavelength and velocity of sound waves] |
| 7. | $I = \frac{E}{A \times t}$ | [Intensity of sound waves] |
| 8. | $L = K \log I$ | [Relation between loudness and intensity of sound waves] |
| 9. | $I.L = 10 \log\left(\frac{I}{I_o}\right)$ | [Intensity level] |
| 10. | $V = 4fL$ | [Velocity of sound waves in terms of frequency of tuning fork and length of air column] |
| 11. | $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ | [Mirror formula] |

| | | |
|---|---|---|
| 12. | $M = \frac{q}{p} = \frac{d_i}{d_o} = \frac{h_i}{h_o}$ | [Magnification formula] |
| 13. | $\frac{\sin\theta_1}{\sin\theta_2} = n$ | [Law of refraction] |
| 14. | $n = \frac{c}{v}$ | [Refractive index] |
| 15. | $n = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$ | [Refractive index of prism] |
| 16. | $n = \frac{1}{\sin\theta_2}$ | [Refractive index in terms of critical angle] |
| 17. | $D = \frac{1}{f}$ | [Power of lens] |
| 18. | $M_\theta = \frac{N}{f} + 1$ | [Magnifying power of simple microscope] |
| 19. | $M_\theta = \frac{L}{f_o} x \frac{N}{f_o}$ | [Magnifying power of compound microscope] |
| 20. | $M_\theta = \frac{f_o}{f_e}$ | [Magnifying power of telescope] |
| 21. | $L = f_o + f_e$ | [Length of telescope] |
| 22. | $F = \frac{kq_1q_2}{r^2}$ | [Coulomb's law] |
| 23. | $K = 9 \times 10^9 Nm^2/C^2$ | [Value of coulomb's constant] |
| 24. | $E = \frac{F}{q}$ | [Magnitude of electric field strength] |
| 25. | $v = \frac{w}{q}$ | [Electric potential] |

| | | |
|---|---|---|
| 26. | $Q = CV$ | [Capacitor equation] |
| 27. | $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$ | [Equivalent capacitance in case of series combination] |
| 28. | $C_{eq} = C_1 + C_2 + \cdots + C_n$ | [Equivalent capacitance in case of parallel combination] |
| 29. | $I = \frac{Q}{t}$ | [Current in terms of charge 'Q' and time 't'] |
| 30. | $V = IR$ | [Ohm's law] |
| 31. | $R = \frac{\delta L}{A}$ | [Resistance of a conductor] |
| 32. | $\propto = \frac{R_f - R_i}{R_o \Delta t}$ | [Temperature co-efficient of resistance] |
| 33. | $R_f = R_i \left[1 + \propto + \Delta T\right]$ | [Final resistance of the conductor] |
| 34. | $R_{eq} = R_1 + R_2 + \cdots + R_n$ | [Equivalent resistance in case of series combination] |
| 35. | $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$ | [Equivalent resistance in case of parallel combination] |
| 36. | $P = \frac{QV}{t}$ | [Power dissipation in electric circuit] |
| 37. | $P = IV$ | [Power dissipated in terms of 'V', 'I'] |
| 38. | $P = I^2R$ | [Power dissipated in terms of 'I', 'R'] |
| 39. | 1 horse power = 746 watt | |

| | | |
|---|---|---|
| 40. | $E = IVt = I^2Rt$ | [Production of heat energy due to power dissipation] |
| 41. | $F = BIL \sin\theta$ | [Magnetic force on current carrying conductor] |
| 42. | $\tau = NBIA$ | [Torque on a current carrying coil] |
| 43. | $\varepsilon = -N \frac{\Delta\phi}{\Delta t}$ | [Faraday, law of electromagnetic induction] |
| 44. | $\frac{N_s}{N_p} = \frac{V_s}{V_p}$ | [Turns ratio for transformer] |
| 45. | $N = A - Z$ | [Relation between number of neutrons, mass number and charge number] |
| 46. | $E = mc^2$ | [Einstein mass-energy relationship] |
| 47. | ${}^{A}_{Z}X = {}^{A-4}_{Z-2}Y + \alpha + Q$ | [$\alpha$ – decay] |
| 48. | ${}^{A}_{Z}X = {}^{A}_{Z+1}Y + \bar{\beta} + Q$ | [$\beta$ - decay] |

OOO

- دنیا کے تمام سونے وجواہرات وقت کے مقابلے میں کوئی حیثیت نہیں رکھتے۔
- وقت کا کھویا ہوا ایک لحہ عمر بھر کے ننھے سے پودے کی کئی شاخوں کو کاٹ ڈالتا ہے۔
- جو وقت کی قدر نہیں کرتا کبھی کامیاب نہیں ہوتا۔